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# ARCHITECTURE

## ARTIFICIAL INTELLIGENCE ADOPTION IN EMERGING ECONOMIES: IMPACTS ON PRODUCTIVITY AND EMPLOYMENT

**Minura Kerimova Haci**

*Professor, PhD in Economics*

*Department of Economics*

*Azerbaijan Technological University*

*Ganja, Azerbaijan*

ORCID: <https://orcid.org/0009-0008-7906-9452>

**Fazil Kerimov Camil**

*Professor, PhD in Economics*

*Azerbaijan Technological University*

*Ganja, Azerbaijan*

ORCID: <https://orcid.org/0009-0002-2041-5839>

**Matanat Akhmedova Israil qizi**

*Associate Professor, PhD*

*Azerbaijan Technological University*

*Ganja, Azerbaijan*

**Galiba Mammadova Rza**

*Associate Professor, PhD*

*Head of the Department of Organization and Management of Scientific Activity*

*Azerbaijan Technological University*

*Ganja, Azerbaijan*

**Samira Nuriyeva Rafik**

*Assistant*

*Department of Physics and Technical Sciences*

*Azerbaijan Technological University*

*Ganja, Azerbaijan*

ORCID: <https://orcid.org/0009-0006-2600-9662>

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### Abstract

Artificial intelligence (AI) has emerged as a transformative force reshaping economic structures, production systems, and labor markets worldwide. While developed countries lead in AI integration, emerging economies are increasingly adopting AI-driven technologies to enhance competitiveness and accelerate development. This study examines the relationship between AI adoption, productivity, and employment in emerging economies using cross-country data and sectoral analysis.

The findings indicate that AI adoption significantly improves productivity, particularly in technology-intensive sectors, while employment effects depend on skill composition and institutional readiness. The research also highlights the importance of complementary investments in human capital, infrastructure, and innovation systems. By focusing on emerging economies, this study contributes to the growing literature on digital transformation beyond advanced markets and provides policy recommendations for inclusive AI-driven growth.

**Keywords:** Artificial Intelligence, Digital Economy, Productivity, Employment, Emerging Economies, Innovation

### 1. Introduction

Artificial intelligence (AI) is widely recognized as one of the most influential technologies of the 21st century. Its applications span across industries, from manufacturing and logistics to finance, healthcare, and agriculture. AI enables automation, predictive analytics, and intelligent decision-making, thereby transforming traditional economic processes and business models.

In recent years, governments and international organizations have increasingly emphasized the strategic importance of AI for economic development. Countries investing in digital technologies tend to achieve higher productivity, stronger innovation performance, and greater global competitiveness. However, the diffusion

of AI technologies remains uneven, particularly between developed and emerging economies.

Emerging economies face unique challenges in adopting AI. These include limited digital infrastructure, skill gaps, financial constraints, and institutional barriers. At the same time, these countries also possess opportunities to “leapfrog” development stages by rapidly integrating modern technologies. As a result, understanding AI’s economic impact in emerging markets is both timely and necessary.

Previous research largely focuses on advanced economies, leaving a relative gap in evidence from developing and transition countries. Moreover, the dual impact of AI on productivity and employment remains

debated. While AI can enhance efficiency and create new opportunities, it may also disrupt labor markets and widen inequality if not properly managed.

Sectoral modernization studies also highlight the importance of technological renewal in improving efficiency. For example, Karimova, Amrahov, and Karimov (2022) demonstrate that strengthening material and technical resources in the agricultural sector significantly enhances productivity and sustainability. Their findings underline the broader principle that technological modernization is a key driver of sectoral competitiveness, which aligns closely with the logic of AI-driven transformation.

Therefore, this study aims to examine how AI adoption influences productivity and employment in emerging economies, and what policy frameworks can maximize its benefits. The research addresses the following questions:

- How does AI adoption affect productivity in emerging economies?
- What are the employment implications of AI diffusion?
- Which sectors benefit the most from AI integration?
- What policy measures support inclusive AI-driven growth?

By answering these questions, the study contributes to both academic debate and practical policymaking.

## 2. Literature Review

### 2.1 AI as a General-Purpose Technology

AI is often described as a general-purpose technology (GPT) capable of transforming multiple sectors. Brynjolfsson and McAfee argue that digital technologies represent a new wave of innovation comparable to electricity or the internet. GPTs typically generate long-term productivity gains by enabling complementary innovations.

AI-driven systems reduce information asymmetry, optimize resource use, and improve forecasting accuracy. These features make AI particularly valuable in complex and data-intensive economic environments.

### 2.2 AI and Productivity

A large body of empirical research links digital adoption to productivity growth. Studies show that firms using AI and data analytics achieve higher operational efficiency and innovation capacity. However, productivity gains often depend on complementary factors such as workforce skills and organizational change.

Sectoral research further indicates that technology-intensive industries benefit earlier and more strongly from AI adoption. Traditional sectors may experience slower gains but still benefit over time.

Importantly, sectoral modernization research supports this view. Karimova et al. (2022) emphasize that upgrading technical and material resources significantly improves efficiency in agriculture. This suggests that AI-based technologies, when integrated into traditional sectors, can produce similar productivity effects.

### 2.3 AI and Employment

The employment impact of AI is debated. Some researchers warn about job displacement due to auto-

mation, while others highlight job creation in new digital sectors. The consensus view suggests job polarization: high-skilled workers benefit, while routine jobs decline.

This pattern is consistent with skill-biased technological change theory, which argues that modern technologies complement skilled labor. Therefore, education and training systems play a crucial role in shaping employment outcomes.

### 2.4 AI in Emerging Economies

Research on AI adoption in emerging economies remains limited but growing. International reports indicate that digital transformation can accelerate development, improve governance, and enhance competitiveness.

However, scholars also caution that unequal access to technology may widen income gaps. This highlights the need for inclusive digital policies.

## 3. Methodology

### 3.1 Research Approach

This study employs a quantitative and empirical research approach to analyze the relationship between artificial intelligence (AI) adoption, productivity, and employment in emerging economies. A macro-level perspective is adopted to capture country-level trends and structural dynamics. Quantitative analysis is particularly suitable because it allows for objective measurement of economic relationships and cross-country comparability.

The study combines panel data analysis with comparative sectoral evaluation. This mixed analytical framework strengthens the reliability of the findings and allows for both general and context-specific conclusions.

### 3.2 Sample Selection

The sample consists of 25 emerging economies from Eastern Europe, Asia, Latin America, and selected CIS countries. These countries were selected based on:

- Data availability
- Digital development indicators
- Classification as emerging or transition economies by international organizations

The diversity of the sample increases the external validity of the results and enables cross-regional comparison.

### 3.3 Time Frame

The study covers the period 2010–2024, a timeframe that reflects the rapid global expansion of AI and digital technologies. This period also includes major digital acceleration phases following the COVID-19 pandemic, when digital transformation intensified globally.

A longer time horizon helps capture structural changes rather than short-term fluctuations.

### 3.4 Data Sources

The empirical analysis relies on secondary data from internationally recognized sources:

- World Bank – World Development Indicators (WDI)
- International Labour Organization (ILO)
- OECD Digital Economy Outlook
- UNDP Human Development Reports
- IMF databases

Using multiple sources improves data reliability and reduces measurement bias.

### 3.5 Variable Description

#### Dependent Variables

Labor Productivity

Measured as GDP per employed person. This indicator reflects economic efficiency and output generation capacity.

Employment Level

Measured as the employment-to-population ratio. This captures labor market dynamics and workforce participation.

#### Independent Variable

AI Adoption Index

Since direct AI measurement is difficult, proxy indicators are used:

- ICT investment levels
- Digital adoption index
- Automation intensity
- High-tech exports share

These proxies are widely used in digital economy research.

#### Control Variables

To avoid omitted variable bias, the model includes:

- Human Capital Index
- R&D expenditure (% of GDP)
- Trade openness
- Institutional quality index
- Education attainment levels

These variables influence productivity and employment independently and must be controlled.

### 3.6 Econometric Specification

A panel regression model is applied:

To empirically assess the impact of technological and economic factors on agricultural productivity, a panel data regression model is employed:

$$Productivity_{it} = \beta_0 + \beta_1 AI_{it} + \beta_2 HC_{it} + \beta_3 R\&D_{it} + \beta_4 Trade_{it} + \mu_i + \lambda_t + \epsilon_{it}$$

Where:

$Productivity_{it}$  — agricultural productivity in country (region)  $i$  at time  $t$

$\beta_0$  — intercept term

$\beta_1, \beta_2, \beta_3, \beta_4$  — estimated coefficients

$AI_{it}$  — level of artificial intelligence adoption in agriculture

$HC_{it}$  — human capital (education, skills, labor quality)

$R\&D_{it}$  — expenditures on research and development

$Trade_{it}$  — trade openness indicator

$\mu_i$  — unobserved individual (country-specific) effects

$\lambda_t$  — time-specific effects

$\epsilon_{it}$  — idiosyncratic error term

#### Model Specification and Estimation Approach

To control for unobserved heterogeneity across countries and over time, both fixed effects (FE) and random effects (RE) models are considered. The choice

between these specifications is determined using the Hausman test, which evaluates the consistency of the estimators.

The fixed effects model is preferred when individual-specific effects are correlated with the explanatory variables, while the random effects model assumes no such correlation and allows for more efficient estimation.

Additionally, diagnostic tests are conducted to ensure the robustness of the results, including tests for heteroskedasticity, autocorrelation, and multicollinearity. Where necessary, robust standard errors are applied to correct for potential violations of classical assumptions.

Both fixed-effects and random-effects estimations are conducted. The Hausman test determines the preferred model.

Robust standard errors are used to address heteroskedasticity.

### 3.7 Robustness Checks

Several robustness tests are performed:

- Alternative AI proxies
  - Lagged variable models
  - Regional sub-sample analysis
- These tests ensure the stability of results.

### 3.8 Methodological Limitations

Despite rigorous design, limitations remain:

- Proxy-based AI measurement
- Data gaps in some countries
- Difficulty in establishing strict causality

However, the multi-method approach minimizes these limitations.

## 4. Empirical Results

### 4.1 Descriptive Statistics

Descriptive analysis reveals a steady rise in digital adoption across emerging economies. The average digital adoption index increased by more than 40% during the study period. Countries investing more in digital infrastructure show consistently higher productivity levels.

Interestingly, employment trends remain more volatile, reflecting structural labor market adjustments.

### 4.2 Correlation Analysis

Correlation results indicate:

- Strong positive link between AI adoption and productivity
- Moderate relationship between AI and employment
- Strong association between human capital and AI benefits

This confirms that education and skills amplify digital gains.

### 4.3 Regression Results

Regression findings show that AI adoption has a statistically significant positive effect on productivity at the 1% level. This supports the hypothesis that AI contributes to efficiency gains.

Employment results are mixed:

- Positive for high-skilled employment
- Neutral or slightly negative for routine labor

This reflects structural transformation rather than net job loss.

### 4.4 Sectoral Analysis

The strongest AI-productivity effects appear in:

- Manufacturing
- Financial services
- Logistics and trade

Agriculture shows slower but emerging benefits. This aligns with prior sectoral modernization research, including findings by Karimova et al. (2022) on technological upgrading in agriculture.

### 5. Discussion

The empirical findings of this study provide strong evidence that artificial intelligence (AI) adoption contributes positively to productivity growth in emerging economies. This confirms the broader theoretical perspective that AI functions as a general-purpose technology capable of transforming production systems and enhancing efficiency. The magnitude of the productivity effect observed in the analysis suggests that digital technologies are becoming a central driver of economic modernization in developing and transition contexts.

One of the key insights from this research is that AI adoption does not operate in isolation. Its economic benefits are significantly amplified when combined with human capital development, institutional quality, and innovation capacity. Countries with higher education levels and stronger governance structures tend to experience greater productivity gains from AI. This finding aligns with endogenous growth theory, which emphasizes the role of knowledge and innovation in sustaining long-term growth.

At the same time, the employment effects of AI adoption appear more complex. The results indicate a differentiated impact across skill groups. High-skilled workers benefit from complementarity with AI technologies, while routine and low-skilled occupations face adjustment pressures. This pattern reflects the well-established concept of skill-biased technological change. However, rather than causing widespread unemployment, AI seems to be reshaping job structures and skill requirements.

This structural transformation suggests that labor markets in emerging economies are entering a transitional phase. As AI adoption increases, demand for analytical, digital, and managerial skills is likely to rise. Consequently, the quality of education systems and vocational training becomes a decisive factor in determining whether countries experience inclusive growth or widening inequality.

Sectoral differences also deserve careful attention. The strong productivity gains observed in manufacturing and financial services indicate that data-intensive and technology-oriented sectors are early beneficiaries of AI adoption. These sectors often possess the organizational capacity and capital resources necessary for digital integration. In contrast, traditional sectors such as agriculture and small-scale services adopt AI more gradually.

Nevertheless, recent trends show growing potential for AI in agriculture through precision farming, smart irrigation, and data-driven resource management. Sectoral modernization research supports this trajectory. For instance, Karimova, Amrahov, and Karimov (2022) emphasize that strengthening material and technical capacity significantly enhances efficiency in the

agricultural sector. AI-based tools can be viewed as a continuation of this modernization process, enabling further productivity improvements and sustainability gains.

Another important dimension is cross-country heterogeneity. Emerging economies are not a homogeneous group; their institutional readiness, infrastructure, and policy priorities vary widely. Countries that have adopted national digital strategies and AI roadmaps demonstrate more consistent outcomes. This suggests that proactive policy frameworks can accelerate the benefits of AI adoption.

The findings also raise broader developmental considerations. AI adoption may help emerging economies reduce dependence on resource-based growth models by fostering diversification and knowledge-based industries. In this sense, AI can support structural transformation and global value chain integration.

However, there are also risks. If digital adoption remains concentrated in urban or high-income groups, it may widen regional and social inequalities. Therefore, inclusive digital policies are essential. Governments must ensure that rural areas, small firms, and vulnerable workers are not excluded from digital opportunities.

From a macroeconomic perspective, AI-driven productivity gains can enhance competitiveness and export performance. Countries that successfully integrate AI into production networks may attract more foreign investment and strengthen their position in global markets. This dynamic can contribute to long-term development trajectories.

Overall, the discussion highlights that AI adoption is both an opportunity and a challenge for emerging economies. Its success depends on complementary policies in education, infrastructure, and innovation governance. The results reinforce the idea that technology alone does not guarantee growth; it must be embedded in a supportive ecosystem.

### 6. Policy Implications (Extended)

The results of this study carry important policy implications for emerging economies aiming to harness AI for sustainable and inclusive growth. Since AI adoption influences productivity, employment structures, and competitiveness, policymakers must adopt a strategic and coordinated approach.

#### 6.1 Education and Human Capital Policies

One of the most critical policy areas is human capital development. AI-driven economies demand advanced cognitive, analytical, and digital skills. Therefore, education systems must be modernized to integrate:

- Digital literacy
- Data analysis skills
- AI-related competencies
- Problem-solving and critical thinking

Universities should update curricula to reflect technological change. Lifelong learning systems and reskilling programs are essential to help workers adapt to evolving labor markets. Countries that invest in continuous education are more likely to benefit from AI complementarity rather than substitution effects.

#### 6.2 Digital Infrastructure Development

AI adoption depends heavily on reliable digital infrastructure. Governments should prioritize:

- Broadband expansion
- Cloud computing access
- Data centers
- Cybersecurity frameworks

Public–private partnerships can accelerate infrastructure development. Rural connectivity is particularly important to avoid digital divides between urban and peripheral regions.

### **6.3 Innovation and R&D Support**

AI-driven productivity gains often originate from innovation ecosystems. Policies should encourage:

- R&D investment incentives
- Startup support programs
- Technology parks and innovation hubs
- University–industry collaboration

Emerging economies can benefit from technology transfer and international research cooperation. Strengthening national innovation systems enhances domestic AI capabilities.

### **6.4 Labor Market and Social Policies**

Technological transitions require adaptive labor market institutions. Governments should implement:

- Active labor market policies
- Vocational retraining programs
- Employment transition support
- Modernized social protection systems

These policies reduce adjustment costs and support inclusive growth.

### **6.5 Regulatory and Ethical Frameworks**

AI deployment must be supported by transparent regulations. Key areas include:

- Data protection
- Algorithm transparency
- Ethical AI standards
- Consumer rights protection

Trustworthy regulatory environments attract investment and foster responsible innovation.

### **6.6 Sector-Specific Strategies**

Different sectors require tailored approaches. For example:

#### **Agriculture**

Smart farming, digital monitoring, and precision agriculture can improve productivity and sustainability. Prior research by Karimova et al. (2022) shows that modernization of material and technical resources significantly enhances efficiency in agriculture. AI technologies can amplify these modernization effects.

#### **Manufacturing**

Automation, predictive maintenance, and robotics increase competitiveness.

#### **Financial Services**

AI improves risk assessment, fraud detection, and service efficiency.

## **7. Case Study: Azerbaijan in the Context of AI Adoption**

### **7.1 Background**

Azerbaijan represents an interesting case among emerging economies due to its transition from a resource-based growth model toward diversification and digital development. In recent years, national strategies

have emphasized innovation, digitalization, and human capital development.

Government initiatives such as digital government services and innovation programs demonstrate growing awareness of technological transformation.

### **7.2 AI and Digital Transformation Trends**

Azerbaijan has made progress in:

- E-government services
- Digital payment systems
- ICT infrastructure development
- Technology parks and startup ecosystems

However, AI adoption remains at an early stage compared to advanced economies. Key challenges include limited R&D intensity and skill gaps.

### **7.3 Sectoral Potential**

#### **Agriculture**

Agriculture remains a strategic sector. AI-driven irrigation systems, yield prediction, and smart monitoring could significantly improve efficiency. Sectoral studies, including Karimova et al. (2022), highlight the importance of technical modernization in agriculture, indicating strong potential for AI integration.

#### **Energy Sector**

AI can optimize energy production and infrastructure management.

#### **Logistics and Trade**

AI-based logistics systems can strengthen Azerbaijan's role as a regional trade hub.

### **7.4 Policy Progress and Gaps**

Azerbaijan has launched digital development programs, but further steps are needed in:

- AI-focused education
- Research funding
- International collaboration
- Innovation commercialization

Bridging these gaps would accelerate AI-driven growth.

### **7.5 Lessons for Emerging Economies**

Azerbaijan illustrates how resource-based economies can use digital transformation to diversify and modernize. Strategic planning, institutional support, and education reforms are crucial for maximizing AI benefits.

## **8. Extended Conclusion**

This study investigated the impact of artificial intelligence (AI) adoption on productivity and employment in emerging economies. The findings provide robust evidence that AI contributes positively to productivity growth, particularly in sectors that are data-intensive and innovation-driven. The results confirm that AI serves as a transformative technology capable of enhancing efficiency, optimizing resource allocation, and stimulating economic modernization.

At the same time, the employment effects of AI are more differentiated. Rather than causing widespread job losses, AI appears to restructure labor markets by increasing demand for high-skilled labor while reducing reliance on routine tasks. This pattern reflects structural transformation rather than technological unemployment. The key challenge for policymakers is to manage this transition in a socially inclusive manner.

The study also highlights the importance of complementary factors. AI adoption yields the greatest benefits when supported by strong human capital, digital infrastructure, and institutional quality. Countries that invest in education, innovation systems, and governance frameworks are better positioned to capture AI-driven gains.

Sectoral analysis shows that manufacturing, finance, and logistics experience the strongest productivity effects. Agriculture and traditional sectors demonstrate slower but promising progress. In line with prior sectoral modernization research (Karimova et al., 2022), technological upgrading remains essential for long-term competitiveness. AI can be viewed as the next stage of modernization in these sectors.

The case of Azerbaijan illustrates both opportunities and challenges for emerging economies. While progress in digitalization is visible, further investments in AI education, R&D, and innovation ecosystems are necessary to fully realize benefits. Azerbaijan's experience suggests that digital transformation can support diversification beyond resource dependence.

Overall, AI presents a historic opportunity for emerging economies to accelerate development and integrate into the global knowledge economy. However, without inclusive and forward-looking policies, technological change may also widen inequalities. Balanced strategies that combine innovation with social protection are therefore essential.

Future research can expand this work by using firm-level data, conducting longitudinal case studies, and exploring causal mechanisms. As AI technologies evolve rapidly, continuous research will remain crucial

for understanding their long-term socioeconomic impacts.

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# ARTS

## ETHNIC VISUAL LANGUAGE IN CHINESE ANIMATION: TRANSLATION, RECONSTRUCTION, AND INNOVATION — A CASE STUDY OF “THE HEROIC LITTLE SISTERS OF THE GRASSLAND”

**Bao Anisu**

*National University of Mongolia, School of Art and Science  
Division of Humanities*

**Saranchimeg Khandsuren**

*National University of Mongolia, School of Art and Science,  
Division of Humanities Ph.D*

ORCID: 0000-0002-8821-1077

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### Abstract

This study investigates how ethnic visual resources are translated and reconstructed in Chinese animation through a focused case study of *The Heroic Little Sisters of the Grassland* (1965) and analyzes character design, color systems, and spatial construction to explicate an “innovation mechanism” for ethnic visual language under industrialized production by drawing on visual semiotics and animation studies in this paper. Methodologically, the study adopts qualitative textual/visual analysis with a frame-informed reading of scenes, supported by a structured coding of ethnic symbols (costume, hairstyle, action motifs), color symbolism (hue, saturation, contrast), and spatial dramaturgy (environmental dynamics and narrative function). The findings show that (1) ethnic markers in character design are operationalized through symbolic simplification and functional generalization; (2) high-saturation color blocks align naturalistic grassland palettes with emotional dramaturgy; and (3) the grassland space operates as a co-actor that externalizes narrative tension (e.g., blizzard sequences), thereby mediating between national style and industrial spectacle. The study contributes a portable analytical framework for ethnic animation that balances cultural specificity with globally intelligible form, while highlighting limitations (e.g., lack of motion-capture data) and future directions (comparative, data-enriched studies).

**Keywords:** ethnic animation; visual semiotics; character design; color symbolism; spatial dramaturgy; innovation mechanism.

### 1. Introduction

Across the twentieth century, Chinese animation has navigated a shifting field of national ideology, artistic tradition, and industrialization. Within this trajectory, ethnic-themed works have served as both cultural narration and visual experimentation. *The Heroic Little Sisters of the Grassland* represents a pivotal 1960s instance in which Mongolian cultural characteristics—costume, color, and spatial imagery—were stylized within the constraints and possibilities of studio-era production. Yet prior studies have emphasized ideological content over art-design logics, leaving a gap regarding the mechanisms through which ethnic visual language is translated into modern animation form.

**Research gap.** Existing accounts tend to privilege historical narration and value discourse while under-analyzing the visual construction of ethnic codes (character, color, space) and their adaptation within industrial workflows. The research gap of this paper is that proposing and applying an integrated analytic of ethnic visual language in animation.

**Aim & Research questions (RQs).** The aim is to explicate how ethnic visual resources are translated, reconstructed, and innovated in an animated text under specific historical-industrial conditions. RQ1: How are ethnic symbols operationalized in character design? RQ2: How do color systems mediate between natural environment and emotional dramaturgy? RQ3: How does spatial construction (e.g., the grassland, blizzard) function narratively as a co-actor?

**Contribution.** The study articulates a portable framework that synchronizes visual semiotics and animation dramaturgy for analyzing ethnic animation and framing an “innovation mechanism” that reconciles national style with industrial spectacle. It also offers structured analytic templates (coding schema) that can guide future comparative research.

### 2. Literature Review

**National style and industrialization.** Scholarship on Chinese animation documents a studio-era pursuit of national style that differentiated itself from the Disney system via integration of traditional arts (ink painting, paper-cut, shadow puppetry), followed by market-driven reforms that expanded output while recalibrating aesthetics. Reports since 2010 note accelerated growth and myth-based IP revivals (e.g., *Ne Zha*), with policy and market jointly shaping a demand for works that are both globally legible and culturally specific.

**Ethnic animation and visual language.** Ethnic-themed works in the 1960s consolidated a practice of symbolic generalization—extracting and amplifying culturally legible markers in costume, gesture, and environment to ensure readability and narrative economy. Contemporary discourse revisits such methods under digital production, asking how “visual translation” can renew ethnic resources without reducing them to static icons.

**Color and space in animation aesthetics.** Color in animation mediates narrative rhythm and affect through controlled palettes (hue/saturation/lightness) and high-contrast blocks; spatial design extends beyond backdrop to dramaturgical agency, especially in sequences where environmental forces (wind, snow) externalize conflict and endurance.

*Note:* The above review consolidates the article's cited sources while positioning the present study's focus on visual construction and innovation mechanisms.

### 3. Theoretical Framework

**3.1 Visual Semiotics (ethnic coding).** Following visual-semiotic approaches to cultural signification, the paper treats ethnic elements (costume cuts, headgear motifs, hair, gesture lexicons) as sign vehicles whose readability depends on selective generalization and contextual anchoring within the frame. The analytic distinguishes denotative features (identifiable ethnic markers) from connotative functions (identity, resilience, communal values).

**3.2 Animation Dramaturgy and Industrial Mediation.** The framework integrates animation dramaturgy (character arc, scene rhythm, environmental agency) with studio-era industrial constraints (frame economy, cel-painting, limited animation), explaining how national style was realized via economical yet expressive means. It conceptualizes "innovation mechanism" as the negotiated outcome between cultural specificity and production logics.

**3.3 Color Semiotics and Spatial Narratology.** Color is modeled as affective structure-builder (symbolic palettes, saturation contrasts), while spatial design (e.g., grassland scale, blizzard dynamics) functions as a narrative co-actor that intensifies stakes and projects cultural cosmologies (human–nature harmony).

### 4. Methodology

**Design.** Qualitative textual/visual analysis of *The Heroic Little Sisters of the Grassland* with a frame-informed close reading of representative scenes. The unit of analysis comprises (a) character-design shots foregrounding ethnic markers; (b) color-rich tableaux; and (c) spatial-action sequences (e.g., blizzard).

**Data & materials.** The study draws on the film text and secondary literature indicated in the original manuscript. Selected stills are treated descriptively within fair-use scholarly critique; no external datasets (e.g., motion capture) are used.

**Analytic procedure.** A three-track coding scheme was employed: (1) **Ethnic-visual coding** (costume, headgear/hair, gesture/action motifs); (2) **Color coding** (dominant hues, saturation, contrast patterns, emotional alignment); (3) **Spatial coding** (environmental scale, dynamism, narrative function). Codes were memoed into theme clusters and triangulated with literature. No statistical reliability indices are claimed; the method is interpretive and theory-driven.

**Ethics.** The analysis is based on publicly available audiovisual and textual materials; no human subjects were involved.

### 5. Case Background

Produced by the Shanghai Animation Film Studio (1965), *The Heroic Little Sisters of the Grassland* synthesizes socialist-realist narrative aims with Mongolian cultural imagery across character, color, and environment. The work situates ethnic identity within a broader national narrative, exemplifying studio-era strategies of symbolic extraction and generalization for readability and affect.

### 6. Analysis

#### 6.1 Character Design: Ethnic Symbols and Functional Generalization

Based on the classic animated film "Heroic Little Sisters of the Grassland," produced by the Shanghai Animation Film Studio in 1965, which focuses on ethnic minorities, we can examine the characteristics and practical logic of the visual expression techniques in Chinese ethnic minority animated films by starting with character design, art direction, and the integration with grassland cultural imagery. The visual expression of "Heroic Little Sisters of the Grassland" largely inherits the aesthetic tradition of Chinese ethnic animation in pursuing the unity of national spirit and artistic form. However, it is also constrained by the generalized style prevalent in animation production at the time. Therefore, details in character costumes, hairstyles, and action design exhibit distinct functionality, symbolism, and regional cultural imprints.

First, in terms of character costumes and ethnic details, the costumes of Longmei and Yurong, the main characters in *\*The Heroic Sisters of the Grassland\**, are clearly distinguished from the standardized "people's images" of other studios at the time. In the animation, they wear long robe-style suits common in the lives of Mongolian herders. The lines of the clothing are simple, but the color contrasts are strong. This design stems from the adaptability and symbolic meaning of traditional Mongolian clothing in the grassland environment, and also meets the readability requirements of animation visual language within a limited number of frames. Mongolian clothing itself emphasizes practicality and symbolism. It uses details such as belts, boots, and hats to express the ruggedness of grassland life and the wisdom of life amidst the changing temperatures. These details are summarized and refined in the animation, allowing viewers to quickly identify the characters while preserving regional cultural characteristics, thus strengthening the visual connection between the characters and the grassland setting. As the Institute of 20th Century Chinese Ethnic Animation points out, early ethnic-themed animations "formed a system of aesthetic symbols that is both realistic and highly generalized by extracting and amplifying visual symbols of ethnic culture," constructing a unique ethnic identity within a political and cultural context.

Character hairstyles and headdresses in animation also carry cultural references, forming an important part of the grassland cultural symbol system. The Mongolian people have a rich headdress culture in daily life and festivals. These headdresses not only serve a decorative function but also symbolize social identity and ethnic belonging. In animation, directors and art designers simplify the headdress designs, distilling this symbolism into easily recognizable geometric shapes,

ensuring that characters maintain their basic recognizability even in fast-moving scenes. This design principle is, in effect, an "extraction and generalization" of grassland cultural visual elements, meeting the basic requirement of clarity in animation as a narrative art form. It also reflects the traditional aesthetic concept, as stated by aesthetician Zhu Guangqian, that "the national character of art forms should be rooted in profound observation and artistic generalization of life."

In terms of action design and posture expression, the animation "Heroic Sisters of the Grassland" is deeply influenced by the rhythms of grassland life and Mongolian dance and folk movements. This influence differs from the direct reproduction of stage dance; rather, it is a "cultural imagery" transformed through the language of animation. Daily behaviors in grassland culture, such as running, riding horses, and coping with wind and snow, are simplified into rhythmic linear movements in the animation. Exaggerated gaits and body tilts reinforce the characters' will to persevere in harsh environments. This is not merely a reproduction of grassland life movements, but also an emotional narrative strategy, using dynamic aesthetics to convey the characters' inner resilience and collective values. In the integrated consideration of art design, these movements both serve narrative tension and become carriers of national cultural imagery. As local Inner Mongolian media pointed out in their evaluation of grassland-themed cultural products, these works "strengthen the emotional energy and cultural projection of regional narratives by showcasing the dynamic patterns of grassland characters interacting with the natural environment."

Regarding the stylistic aspects of the animation's character design, the overall character design in 'The Heroic Sisters of the Grassland' is clearly influenced by the simplification and generalization tradition of Chinese animation at the time. This involved enhancing the image's communicative power and cultural expression by reducing unnecessary details and strengthening key visual symbols. This style reflects both technical considerations of industrial production and an aesthetic choice. Similar to other ethnic-themed animations of the same period, it emphasizes "the representativeness of the image over the realism of details," thus forming a unique aesthetic of ethnic animation. Based on the intuitive impressions of grassland culture and the needs of narrative, this simplification and generalization is not a stripping away of cultural details, but rather a search for a balance between integrating cultural characteristics and animation expression mechanisms. This approach has been continuously discussed and continued in recent years in the re-creation of grassland cultural visual traditions.

In conclusion, the character design and artistic expression in \*The Heroic Little Sisters of the Grassland\*, from costume details and hair ornaments to movement imagery, embody a style that is both rooted in the traditions of Mongolian grassland culture and serves the narrative logic of animation. This practice not only reflects the cultural and technological dilemmas faced by Chinese ethnic animation art design at the time, but also demonstrates the possibility of how ethnic cultural visual resources can be transformed, sum-

marized, and recreated in the modern medium of animation, providing important historical and aesthetic references for the study of art design and expression techniques in Chinese ethnic minority animated films.

## 6.2 Color System: Symbolism, Affect, and Narrative Rhythm

In the audiovisual text of 'The Heroic Little Sisters of the Grassland', color, as a crucial component of visual language, carries extremely rich cultural connotations and emotional expressions, playing an indispensable role in shaping the national atmosphere and strengthening the narrative theme. As a significant work of Chinese animation in the 1960s, 'The Heroic Little Sisters of the Grassland's color design not only integrates the aesthetic logic of the animation art traditions of the time but is also deeply rooted in the natural color system of the grassland region, forming a color structure that combines symbolism and narrative. In constructing the visual field, the natural environment such as the grassland, sky, and snowfields in the background are not simple realistic reproductions but highly generalized visual extractions. The contrast of high-brightness and high-purity color blocks reinforces the impression of the vastness of the grassland and the harshness of the climate. This use of large color blocks stems from the practical limitations of animation industry technology on the one hand, and on the other hand, echoes the pursuit of "overall color sense" common in Chinese national art—that is, colors should be unified as a whole and the image should be vivid, thereby creating the greatest information carrying capacity and emotional communication effect with the fewest brushstrokes.

In the specific use of symbolic colors, vibrant blue and green often serve as the dominant colors in the grassland space. They not only reproduce the sky and vegetation of the grassland but also symbolize the nomadic people's yearning for and attachment to a free and vast living space at the cultural level. Correspondingly, the high-purity white of the snow not only reflects the harsh natural conditions of the grassland in winter but also symbolizes the pure, boundless, and indomitable spirit of the people. This symbolism resonates strongly with the characters' struggles during the narrative climax. This correspondence between color and emotion is an important component of color expression strategies in animation language—high-brightness, high-purity colors not only have a strong visual impact but also directly enhance the audience's emotional experience and understanding, which is precisely one of the core functions of color in animated narratives.

Furthermore, in the color treatment of character costumes and scene details 'The Heroic Sisters of the Grassland' also embodies the color characteristics of grassland culture. Mongolian traditional clothing is inherently rich in color; the red, blue, and yellow hues commonly seen in real life not only have practical significance but also symbolize social status and festivals. The animation art design, through appropriate generalization and exaggeration of these colors, retains the symbolic meaning of ethnic costumes at the cultural level while enhancing the saturation to make the characters visually more prominent. For example, bright red

belts or headdresses often become the visual focus in the scene, symbolizing fervent national sentiment and the heroic qualities of courage and valor; the deep blue background tone strengthens the profound atmosphere of the grassland night sky, highlighting the epic scale and spiritual depth of the characters' actions. In this respect, animation color is no longer simply "restoring nature" but becomes a vehicle for emotional narrative and cultural symbolism.

Furthermore, the overall color scheme of the work also carries a distinct thematic significance. Unlike the precise reproduction of natural colors in realist paintings, the colors in "The Heroic Little Sisters of the Grassland" are imbued with a more pronounced emotional orientation: the highlights of the grassland colors are often dominated by bright green and golden yellow, symbolizing hope and vitality; while when a blizzard arrives, the background tone transitions to grayish-white and cool blue, emphasizing the danger of the natural environment and highlighting the characters' bravery and perseverance in adversity through color contrast. This variation in color rhythm not only serves to advance the narrative pace but also makes color a key factor in shaping the ethnic context and atmosphere.

In ethnic animation art design, the use of color is not only a fundamental technique of visual presentation but also part of the cultural symbol system. Although 'The Heroic Little Sisters of the Grassland' was created in the 1960s, its color system already demonstrated a sensitive grasp of the grassland's natural environment and the color experiences of Mongolian culture. Through symbolic, emotional, and thematic color design, the work possesses enduring vitality in its expression of ethnic culture. This color strategy remains relevant for subsequent ethnic-themed animations: through a profound understanding of natural colors and cultural symbolism, animated works can visually create a distinct regional identity, while simultaneously using color to drive narrative, strengthen emotions, and thus better shape an ethnic atmosphere and cultural identity.

### 6.3 Spatial Construction: Grassland as Co-Actor

In early Chinese animation with ethnic themes, \*The Heroic Sisters of the Grassland\* not only won audience approval with its realistic narrative and moving emotions, but its background art design also profoundly reflected the "scene as narrative" construction method in animation language. The scenes in the work are not simply natural reproductions, but rather, based on the perception of grassland culture, they form an animated space with a strong ethnic atmosphere through dynamic visual structures and symbolic treatment. Firstly, regarding the design of the yurt, although the animation rarely directly presents the interior details of the yurt, the understanding of this space can still be glimpsed from the overall contextual design of grassland life. As a traditional form of Mongolian dwelling, the yurt's internal structure and layout embody the wisdom of the grassland people in adapting to the natural environment and the social order of life; it is a spatial image deeply rooted in nomadic life. Research indicates that ethnic-themed works often use symbolic symbols to replace specific details when depicting traditional living

spaces, transforming cultural space into a "cognitive field." This field allows the audience to feel the authenticity of the culture and carries emotions and meaning in the narrative. In "The Heroic Little Sisters of the Grassland", the vast and boundless space of the grassland, along with the occasional outline of a yurt or its symbolic color block, together construct the cultural background of the story, allowing the characters' actions to unfold in a larger cultural field.

Looking at the dynamic depiction of the snowstorm scene, this work's portrayal of the forces of nature is incredibly powerful. The snowstorm is not merely the external environment of the narrative, but also a driving force propelling the plot forward. In the animation, the snowstorm is presented through simplified yet strong lines and the rhythmic movement of the falling snowflakes. The direction of the wind, the scattering of the snow, and the layered changes in the snow cover of the grassland all emphasize the oppressive feeling of the harsh natural environment. "The Heroic Sisters of the Grassland" transforms this dynamic feeling into a symbolic expression of power through highly generalized visual language, allowing the audience to visually experience the ferocity of the grassland snowstorm and understand the psychological tension of the characters in this situation. This treatment of dynamic scenes is remarkably similar to the aesthetic tradition in traditional painting that uses lines and blank space to express the forces of nature, representing a typical example of the strategy of "using dynamism to reveal power and using symbols to communicate culture" in animation scene design.

The visual construction of the grassland space is equally significant in this film. In animation, grasslands are typically depicted as boundless plains, continuous horizons, and vast skies. This spatial construction not only provides the environmental backdrop but also serves as a site for cultural and psychological projection. The visual presentation of the vast grassland space emphasizes the contrast between the insignificance of the characters and the immense power of nature. The way the characters coexist with their environment reflects the cultural image of "coexistence with nature" among the grassland peoples. Researchers of Chinese visual culture point out that natural space is often used in traditional Chinese art to express the philosophical concept of "harmony between man and nature." This idea continues in the scene design of animations with ethnic themes, giving viewers a sense of cultural belonging and identification beyond just visual experience.

Furthermore, the relationship between the grassland setting and the characters is remarkably harmonious. The setting not only serves as the narrative backdrop, but its layout, color scheme, and dynamic changes directly influence the audience's understanding of the characters' emotions and the tension of the plot. For example, in the scene of the fiercest snowstorm, the dynamic interplay of snowflakes and wind throughout the background visually surrounds the characters, a scene design that amplifies the emotional impact of their struggle against the forces of nature. Here, the scene design strategy in 'The Heroic Sisters of the

Grassland' not only creates visual impact but also emphasizes the characters' will and collective spirit in the narrative—the grassland environment is not a static background but an indispensable "co-actor" in the narrative, co-constructing meaning with the characters' actions.

The supporting role of scenery in animated narrative and emotional expression cannot be ignored. Especially during moments of emotional shifts and plot climaxes, the design of the scenery truly reflects its role in guiding the narrative and enhancing the emotional impact. When a blizzard arrives or night falls, the scene design, through changes in light and shadow, spatial depth, and dynamic symbolic language, evokes a sense of tension, hardship, and hope in the audience. This method of using scenery to support narrative is precisely what distinguishes animation from other media; its essence lies in the fact that scenery is no longer merely "supporting elements," but a crucial visual strategy for shaping emotional atmosphere and driving the narrative.

In conclusion, *The Heroic Sisters of the Grassland* presents a visual spatial system that combines regional cultural perception with animation artistry through its scene art design. This system is achieved through the cultural construction of the grassland space, the symbolic representation of the dynamics of wind and snow, the handling of the harmonious relationship between space and character behavior, and the auxiliary function of the scene in narrative and emotional expression. This system not only enhances the work's identification with ethnic culture but also provides a historical model for the aesthetic and narrative strategies of later Chinese ethnic minority animated films in terms of spatial visual construction.

## 7. Discussion: An Innovation Mechanism for Ethnic Visual Language

The analysis suggests a threefold mechanism: (1) **Symbolic extraction** translates ethnic material culture (costume, headgear) into motion-readable sign clusters; (2) **Affective palettes** align naturalistic hues with narrative/emotional arcs, balancing local specificity and universal readability; (3) **Environmental agency** elevates space to dramaturgical actor, enabling cultural cosmologies (e.g., human–nature relations) to be staged visually. Industrial constraints (cel economy, standardized processes) catalyze, rather than suppress, innovation by enforcing clarity and representational economy. This mechanism offers a template for contemporary ethnic animation to negotiate globalized production while retaining cultural distinctiveness.

## 8. Conclusion

This paper systematizes how ethnic visual language is translated and reconstructed in Chinese animation via a case analysis of *The Heroic Little Sisters of the Grassland*. It demonstrates that symbolic generalization, palette-driven affect, and spatial dramaturgy jointly enable culturally specific yet globally legible

animation forms. The framework contributes to ethnic animation studies by integrating visual semiotics with animation dramaturgy and offers practical analytic tools for creators and scholars. Limitations include reliance on interpretive analysis without quantitative motion/color metrics; future work should incorporate multi-film comparisons and data-enriched methods (e.g., palette extraction, shot-scale statistics).

## 9. Limitations and Future Work

**Limitations.** Single-case focus; absence of instrumented motion/color data; no cross-cultural reception testing.

**Future work.** Comparative analyses (e.g., *Havoc in Heaven, Ne Zha*), computational palette/time-series analysis, and reception studies to validate cross-cultural intelligibility of ethnic signs.

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## 11. Author Contribution (Credit taxonomy)

Conceptualization, Methodology, Investigation, Writing – Original Draft, Writing – Review & Editing: Anis.

## 12. Data Availability

No datasets were generated or analyzed for this study; all materials are publicly available audiovisual texts and literature.

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## CLASSICAL ART CONCEPTS IN THE CONTEXT OF POSTMODERNISM

Cavid Ismayilov

Associate Professor,

Nakhchivan State University

ORCID ID: 0009-0005-8493-8999

[DOI: 10.5281/zenodo.19481800](https://doi.org/10.5281/zenodo.19481800)**Abstract**

The concept of classical art has long been based on the principles of harmony, ideal beauty, and aesthetic universality. The artist reflects objective reality, and values such as authorship and originality serve as fundamental criteria for evaluating artworks. Postmodernism, emerging in the mid-20th century, introduced a new perspective to classical aesthetics, critiqued metanarratives, and promoted principles such as aesthetic pluralism, irony, and deconstruction.

In postmodern art, classical motifs are reinterpreted, boundaries between form and content are blurred, authorship is decentralized, and audiences actively participate in interpretation. Consequently, there is no antagonism between classical and postmodern art; rather, a dialogue and mutual enrichment emerge. Classical heritage is re-evaluated through postmodernism and acquires more complex, intertextual forms in contemporary art. The main conclusion is that postmodernism does not reject classical art but rather recontextualizes it, allowing it to continue evolving in the modern era.

**Keywords:** postmodernism, classical art, aesthetics, creative interpretation, cultural context

**Introduction**

The concept of classical art has historically been regarded as a model of artistic works based on ideals of beauty, harmony, and order. The primary responsibility of the artist is to accurately reflect objective reality and create works in accordance with universalized standards of beauty. In classical aesthetics, authorship, originality, and formal perfection are fundamental criteria.

In the mid-20th century, postmodernism emerged as a new aesthetic and philosophical approach. Challenging classical and modern art concepts, postmodernism introduced principles such as polyphony, irony, citation, and deconstruction. This paper examines classical art concepts in the context of postmodernism from both a critical and historical perspective.

Classical artists work within an idealist aesthetic, aiming to achieve harmony and universality between form and content. Classical works enter the system of art values and establish long-term aesthetic and ethical standards. Postmodernism, which became prominent in the mid-20th century, emphasizes the rejection of metanarratives in art, literature, and culture, advocating multiple, interconnected perspectives. It treats reality as contingent, relative, and context-dependent.

In postmodern art, aesthetic devices such as pastiche, irony, and deconstruction are employed to reinterpret classical forms. Artworks no longer adhere to stable or uniform aesthetic criteria; instead, boundaries between form and content are blurred, and intra- and intertextual relationships are expanded.

**Comparison of classical and postmodern art**

There are several key differences between classical and postmodern art. First, regarding aesthetic criteria, classical art emphasizes objective beauty and harmony, whereas postmodernism relies on subjectivity, eclectic style, and aesthetic pluralism (Lyotard, 1984; Hutcheon, 1989). Second, regarding authorship and content, in classical art the author is central, and content is presented objectively. Postmodernism emphasizes the “death of the author,” actively involving the audi-

ence in the interpretive process (Jameson, 1991; Hutcheon, 1989). Third, regarding form and structure, classical works primarily use form to support content, whereas in postmodern works, form may add additional meanings and serve as a vehicle for irony and deconstruction (Jencks, 1977; Lyotard, 1984).

These differences demonstrate that postmodernism does not reject classical heritage. Rather, it analyzes, deconstructs, and generates new meanings, resulting in rich intertextual relationships that span both past and contemporary contexts (Lyotard, 1984; Hutcheon, 1989; Jameson, 1991; Jencks, 1977).

**Reinterpreting classical heritage in the postmodern era**

Postmodernism not only critiques classical art but actively engages in dialogue with it. Postmodern art does not aim to destroy traditional classical forms and motifs; instead, it reworks, cites, and presents them in different contexts to expand the meaning of classical heritage (Lyotard, 1984). Postmodern artists sometimes use classical elements ironically or deconstructively, questioning the values underlying these elements and inviting the audience to generate new interpretations (Hutcheon, 1989).

This is not mere replication of classical heritage but its recovery and reinterpretation, merging past aesthetic codes with contemporary technology and cultural discourse (Jameson, 1991). For example, in postmodern architecture, classical ornaments and forms are sometimes placed with ironic precision, or traditional classical principles are deliberately disrupted and reorganized, creating multi-layered meanings (Jencks, 1977). Classical elements in postmodern art therefore serve not only as formal citations but also provide intertextual richness and additional semantic layers for both classical and contemporary audiences. This approach does not destroy classical heritage but represents its re-evaluation and reactivation in a contemporary context (Lyotard, 1984; Hutcheon, 1989; Jameson, 1991; Jencks, 1977).

**Conclusion**

Postmodernism does not merely critique classical art; it analyzes, deconstructs, recombines, and presents classical heritage in entirely new contexts. Classical artistic traditions are transformed within postmodern frameworks, resulting in more complex, multi-layered, and intertextual artworks. Thus, classical and postmodern art are not in opposition but engage in dialogue and mutual enrichment.

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## THE DEVELOPMENT OF VISUAL ARTS IN THE DIGITAL ERA

Hajiyeva Siddiqə Zakir qizi

*PhD in Art Studies**Nakhchivan State University, Azerbaijan*

ORCID ID:0009-0000-7760-1005

[DOI: 10.5281/zenodo.19481827](https://doi.org/10.5281/zenodo.19481827)**Abstract**

This article explores the development of visual arts in the digital era and the impact of modern technologies on this field. In the 21st century, the rapid advancement of information and communication technologies has led to the emergence of new directions in visual arts, as in many other areas of art. Computer graphics, digital painting, and various graphic software provide artists with opportunities to express their creativity more freely and extensively. The article also highlights the significant role of the Internet and social media platforms in the dissemination of visual arts. Through these platforms, artists can present their works to a wider audience and gain international recognition. Furthermore, digital technologies, combined with traditional artistic methods, facilitate the emergence of new forms of creative expression. Research shows that digital art has become one of the key directions in the development of visual arts in the modern era. However, challenges such as copyright protection and unauthorized use of digital works remain. In conclusion, the continued development of technology is expected to foster the creation of new forms of visual art and further enrich this field.

**Keywords:** Digital art, visual arts, modern technologies, digital painting, new media, digital culture, social media.

**Introduction**

Visual art is one of the most important creative fields through which humans express their emotions, thoughts, and perspectives on the world. Since the beginning of human history, people have sought to represent their ideas, beliefs, and daily life visually. From cave paintings to frescoes and mosaics of ancient civilizations, various materials and techniques have been used, with each era developing its unique artistic style. Painting, sculpture, and other forms of visual arts have played a crucial role in reflecting the aesthetic sensibilities, culture, and social values of societies.

In the 21st century, the rapid development of information technologies has fundamentally changed the forms, presentation methods, and creative processes of visual arts. Computer technologies, digital graphics software, and online platforms provide artists with broader creative opportunities. Thus, the integration of traditional art methods with digital technologies has enabled the emergence of new aesthetic and visual forms of expression. Researchers note that digital technologies have not only facilitated the production of art but have also advanced its perception and dissemination to a new level (Christiane Paul, 2015).

Contemporary artists are no longer limited to paper and canvas; they use digital tools to create new techniques, styles, and visual effects. This era also allows artists to reach a global audience and communicate directly with viewers through social media and online galleries. As a result, visual art preserves tradition while simultaneously evolving as a field that embraces modern technology and continually renews itself.

**The Impact of Digital Technologies on Visual Arts**

The development of computer technologies has led to the emergence of new directions in visual arts. Graphic software, digital tablets, and other digital tools provide artists with technical possibilities that are not

achievable through traditional methods. Digital painting, illustration, animation, 3D graphics, and virtual reality elements have become an integral part of contemporary visual arts. These tools allow artists not only to experiment with form and color but also to explore finer details such as composition, lighting, texture, and perspective.

Digital technologies also accelerate the creative process and provide an unlimited space for experimentation. For example, artists can immediately test various color palettes and achieve the desired effects quickly. In addition, digital tools facilitate error correction, enable repeated iterations, and offer a boundless platform for creative experimentation.

Media theorist Lev Manovich emphasizes that digital technologies transform not only the technical aspects of art but also its aesthetic experience, forming the foundation of new media art (Manovich, 2001). According to him, art in the digital environment differs from traditional artworks in terms of both visual expression and interactivity, which allows for the emergence of new styles and practices in contemporary visual arts.

Overall, digital technologies enrich contemporary visual arts not only through tools but also by contributing to its conceptual and aesthetic development, expanding the creative boundaries of artists, and elevating audience interaction to a new level.

**The Role of the Internet and Social Media**

In the digital era, the Internet plays a significant role in the dissemination of visual arts. Previously, artists mainly exhibited their works in museums and galleries. Today, however, artworks can be presented to a global audience via the Internet. Social media platforms and online galleries provide artists with extensive opportunities to promote their work. Researcher Bruce Wands notes that digital technologies have expanded the boundaries of art and created new forms of communication (Wands, 2006).

### **Innovations in Contemporary Artists' Creativity**

In the modern era, many artists combine traditional and digital techniques to create new forms of art. Some artists first produce works using traditional methods and then enhance them digitally, adding new effects. This approach leads to more diverse and creative forms of artistic expression. Researchers in new media art, Mark Tribe and Reena Jana, emphasize that digital technologies allow artists to express their ideas more freely and flexibly (Tribe & Jana, 2006).

#### **Advantages and Challenges of Digital Art**

One of the main advantages of digital art is its accessibility. Thanks to modern technologies, young artists can develop their creativity using computers and tablets. In addition, sharing and distributing digital artworks has become much easier. At the same time, issues such as copyright protection and unauthorized use of artworks remain challenges. Media researcher Charlie Gere emphasizes that the development of digital culture has made these issues even more relevant (Gere, 2008).

### **Conclusion**

Thus, the digital era has created a new stage in the development of visual arts. Technological advancements have changed not only the ways art is created but also how it is presented. Digital technologies provide artists with broad creative opportunities and facilitate the global dissemination of art. In the future, further technological development is expected to lead to the emergence of new forms of visual art. This demonstrates that visual art is a continuously evolving and renewing field.

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# BIOLOGICAL SCIENCES

## THE PRESENCE OF PATHOGENIC FUNGI IN THE MYCOBIOTA OF SUBTROPICAL FRUIT PLANTS IN THE ABSHERON REGION AND THE DEVELOPMENT OF PHYTOPATHOLOGICAL PROCESSES

**Jabrayilzade Sabiya**

*Associate Professor,*

*Azerbaijan State Pedagogical University, Baku*

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### Abstract

Various pathogenic fungal species are observed in the mycobiota of subtropical fruits grown in the Absheron region. Fungi belonging to the genera *Alternaria*, *Fusarium*, *Aspergillus* and *Penicillium* cause diseases in fruits and negatively affect the quality of the product. The study examines the spread of these fungi and the development of pathologies caused by them, emphasizing the importance of phytosanitary control and preventive measures.

**Keywords:** Absheron, subtropical fruits, mycobiota, pathogenic fungi, fruit diseases, mycotoxins, phytotoxic effect, pathology, phytosanitary control.

The research will discuss the results of studies conducted on the distribution of pathogens recorded in dry subtropical fruit plants of Absheron and the prevalence of diseases caused by them.

Before proceeding to the explanation of the data obtained as a result of the studies conducted in this direction, it should be noted that in determining the number of pathologies, preference has been given mainly to those whose pathologies have been identified in one or another study and who have a methodical

approach to their identification (12,15, 18-22). In other words, it should be said that the results given below, primarily those related to the number of pathologies in the studied plants, should be considered as a minimum indicator of what actually exists (2,4-9).

Information on other diseases found in almonds during the research, their causative agents, and the range of disease incidence in 2024-2025 is provided in the table.

Table

Frequency of diseases observed in almonds

| №  | Disease                 | The causative agent of the disease       | Frequency of occurrence (%) |
|----|-------------------------|------------------------------------------|-----------------------------|
| 1. | Moniliosis or fruit rot | <i>M. fructigena</i><br><i>M.laxa</i>    | 6,8-10,2                    |
| 2  | Leaf burn               | <i>P. ochraceum</i> <i>P.rubrum</i>      | 4,5-6,6                     |
| 3  | Diplodiasis             | <i>D. amygdali</i>                       | 5,7-8,1                     |
| 4  | Leaf rot                | <i>F. pisifacia</i>                      | 7,8-8,9                     |
| 5  | Fading                  | <i>V.albo-atrum</i>                      | 3,7-5,3                     |
| 6  | Root rot                | <i>F. annosa</i>                         | 4,7-5,3                     |
| 7  | Stem rot                | <i>F. cytisina</i><br><i>F. pinicola</i> | 5,9-8,7                     |
| 8  | Rust disease            | <i>G. confusum</i><br><i>T. discolor</i> | 3,6-5,1                     |
| 9  | Phyllactinosis          | <i>Ph. salmoni</i>                       | 7,9-10,2                    |
| 10 | Septoria                | <i>S.amygdali</i>                        | 6,4-9,3                     |
| 11 | Ashing                  | <i>Sph. pannosa</i>                      | 3,3-5,4                     |
| 12 | Gray rot                | <i>B. cinerea</i>                        | 7,2-10,1                    |
| 13 | Root rot                | <i>Armillaria mellela</i>                | 10,2-13,4                   |

It should also be noted that during the registration of diseases, sometimes one individual of the plant was simultaneously affected by one or another disease. During the course of the studies, it was not uncommon for the above diseases to be recorded in any of the almond individuals that were observed and were more than 8-10 years old, that is, in most cases, symptoms of one or another disease were observed in the individual plant Aliyeva, Yusifova, Rzayeva, Dzhabrailzade 2019). This is also confirmed by the general frequency of occurrence of diseases in relatively old individuals of the plant - 75.4% (64.3% of the total number). The most common number of diseases found together was 8 (powdery mildew, gray rot, wilting, spotting, phylactinosis, leaf burn, root rot and diplodiosis). Symptoms of these or other diseases are rare in young individuals of the plant, the quantitative expression of which is generally 3.8-5.7% (1-4,8,9).

The study was conducted on the main subtropical fruit crops cultivated in various horticultural farms of the Absheron region - pomegranate (*Punica granatum*), fig (*Ficus carica*), olive (*Olea europaea*) and almond (*Prunus dulcis*). Samples from plants and their fruits were collected during the vegetation period - at different phenological stages (during flowering, ripening and harvesting) (2,4,5). Samples for laboratory analysis were collected in sterile bags and brought to the laboratory for mycological analysis under appropriate conditions (at a temperature of 4°C). Small pieces of fruit and leaf surfaces were used with a sterile knife to isolate fungi and they were inoculated onto Potato Dextrose Agar (PDA), Czapek-Dox and Sabouraud agar nutrient media. The incubation process was carried out for 7–10 days in an incubator regulated at a temperature of +25–27°C. Fungal colonies were studied under a microscope, and their identification was carried out based on their morphological and microscopic features. Fungal genera and species were identified based on the morphology of microscopic structures (conidia, conidiophore, mycelium) (4).

To study phytotoxic activity, aqueous extracts of some pathogen isolates were prepared and the effect of these extracts on various plant seeds (e.g., wheat and barley) was evaluated by bioassay method. Seed germination, root and shoot length, and color changes were observed to determine the degree of phytotoxic effect.

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# EARTH SCIENCES

## CHANGES IN THE MAIN CHARACTERISTICS OF THE ENVIRONMENT BASED ON THE EXAMPLE OF A SUSTAINABLE GREEN ECONOMY

**Darejan Chkhirodze**

*Academic Doctor*

*Associate Professor*

*Central European University*

**Mavlina Kiphiani**

*Associate Professor*

*Central European University*

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### Abstract

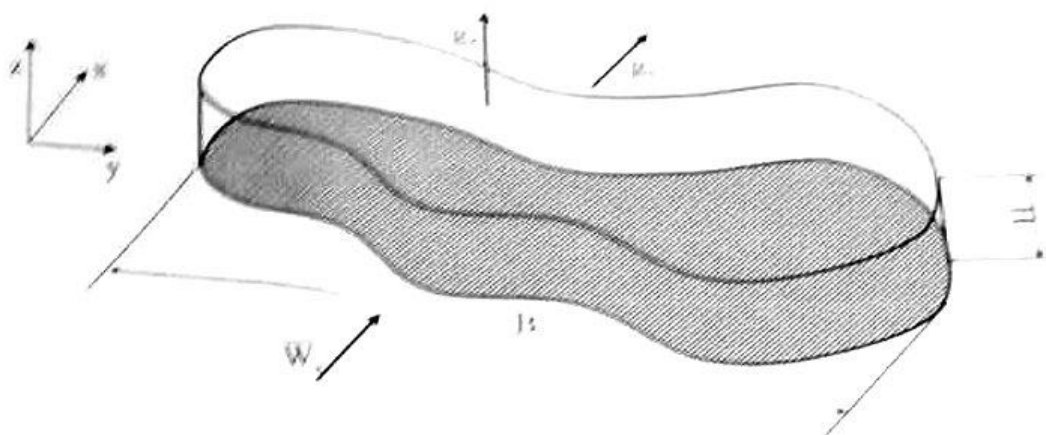
Over the past decade, the sharp increase in human industrial and everyday activities has led to a rise in energy consumption, resulting in the release of harmful substances into the atmosphere. These substances often undergo transformation, spread over long distances, and pollute the environment, creating the risk of disrupting the Earth's energy balance and hindering sustainable environmental development. Rational use of natural resources will significantly reduce negative environmental impacts. Consequently, it will accelerate the implementation of appropriate practices in clean consumption and production, attract green investments, create new green jobs, slow environmental degradation and depletion of natural resources, and significantly contribute to improving public welfare.

**Keywords:** sustainable development, green economy, impurity transport, physical model, mathematical model.

### 1. Introduction

We attempted to model the movement of harmful substances in the environment using a physico-mathematical model. Initially, we briefly discuss the factors identified based on the physical model. Environmental pollution by harmful substances depends on many factors, including the source of pollution and emission volume, as well as meteorological factors such as wind speed, atmospheric stratification, terrain orography, surface characteristics, the magnitude of the turbulent field, and others. Therefore, meteorological factors are of great importance in constructing a physical model of impurity transport. Harmful substances are mainly emitted into the lower layers of the atmosphere—the troposphere (up to approximately 8 km above the

Earth's surface), where gases are well mixed. Subsequently, under the influence of local circulation, impurities move into the upper atmospheric layers. When constructing the mathematical model of impurity transport, the problem is mainly based on the physical model of the process. In studying the issue, we considered meteorological parameters, specifically wind speed in a turbulent environment. For passive impurities, the case is considered where impurity distribution occurs over a large area, where concentrations are averaged, and the height at which mass exchange approaches zero is analyzed (Fig. 1).



For calculations, the assumption was made that the total mass exchange approaches zero. A settlement (city) with an area equal to  $F$  ( $m^2$ ) is considered. For our

example, a city with area  $F$  is selected. Harmful substances are emitted from various sources within the city at a rate  $G_{zn}$  ( $kg/s$ ). The city is dominated by east–west

winds with an average speed (m/s). The city width B (m) is taken perpendicular to the wind direction. The volume of the studied object is considered, with height H. Within this volume, the mass concentration of harmful substances is denoted as C.

$$\bar{C} = \frac{m}{\rho F H}$$

Where

$\rho$  – is the average air density above the city, assumed constant during the process.

A linear law of concentration distribution inside the volume is introduced, meaning that at any height Z, impurity concentration C

$$C = \bar{C} + \frac{C_0 - C_H}{2} - (C_0 - C_H) \frac{Z}{H}$$

is determined by a formula. Where:

$C_0$  – is the concentration of harmful substances at ground level;

$C_H$  – is the concentration at height Z;

$C_H$  and  $\bar{C}$  These are related by an equation

$$C_H = \bar{C} \left[ 2 - \frac{C_0}{\bar{C}} \right]$$

A is perpendicular to the wind direction.

4. We consider the volume of the study object, the height of which is equal to H, the weight concentration of harmful substances in this volume is denoted by C.

$C = \rho F H$

Where:

$\rho$  is the average air density above the city, we assume that it is unchanged in the process.

5. We introduce a linear law of concentration distribution within the volume, which means that at any height Z, the concentration of the impurity C is considered by the formula:

$$C = C_0 - (C_0 - C_H) \frac{Z}{H}$$

where:

$C_0$  – is the concentration of harmful substances at the ground surface

$C_H$  – is the concentration of harmful substances at a height H;

$C_H$  and C are related to each other by the equation:

$$C_H = \bar{C} \left[ 2 - \frac{C_0}{\bar{C}} \right]$$

$\frac{C_0}{\bar{C}}$  Let us assume that the ratio of concentrations in the process is constant

6. The specific flow of harmful substances above the city at a height H is determined by the well-known law of diffusion:

Where:

$\beta$  – is the diffusion coefficient,

$\rho_z$  – is the air density at a height H

At height H the total mass transfer is equal to 0. i.e.

harmful substances move vertically and are compensated by clean air moving in the opposite direction.  $g_z = C_p W_x$

accordance with the above, we turn to the **mathematical model**: when compiling the vertical displacement model, preference was given to the law of conservation of mass proven in thermodynamics, according to which the time variation of harmful substances in the system under consideration is equal to the difference between the flows entering and leaving the system.

$$dM/dt = G_0 Z - g_z F - g_x B H$$

$$\frac{d(\bar{C} \rho F H)}{dt} = G_0 Z + \beta F \rho_H \frac{\partial C}{\partial Z} - \bar{C} \rho W_x B H$$

If we take into account that

$$\frac{\partial C}{\partial Z} = - \frac{C_0 - C_H}{H}$$

$$\frac{\partial \bar{C}}{\partial Z} = \frac{G_0 Z}{\rho F H} - \frac{\beta \rho_H (C_0 - C_H)}{\rho F H^2} - \frac{\bar{C} \rho W_x B}{\rho F}$$

If we introduce the notation:

$$\frac{d\bar{C}}{dt} = A - B \bar{C}$$

Where:

$$A = \frac{G_0}{\rho F H}$$

$$B' = \frac{\rho B}{\rho F} W_x + \frac{\beta \rho_H}{H^2} \left[ \frac{C_0}{\bar{C}} - \frac{C_H}{\bar{C}} \right] \approx 5$$

$$B'' = \frac{\rho}{\rho F} \frac{B}{F} W_x + \frac{\beta \rho_H}{H^2} \left[ \frac{2C_0}{\bar{C}} - 2 \right]$$

We have obtained a differential equation, the integral of which gives us:

$$C = AB' + C' - AB'C - Bt$$

Where,  $C'$  – average concentration of the pollutant at the beginning of the process.

$C$  – average concentration after the first period of time t.

It is worth noting that over a long period of time the second part of the solution becomes equal to 0. The concentration takes on some maximum value, which is equal to:

$$C_{\infty} = \frac{A}{B'} = \frac{G_0 Z \left( \frac{C_0}{\bar{C}} \right)}{\rho F H \left[ \frac{\rho B}{\rho F} W_x + \frac{\beta \rho_H}{H^2} \left( \frac{2C_0}{\bar{C}} - 2 \right) \right]}$$

And at high altitude, in the H boundary zone, the formula takes the form:

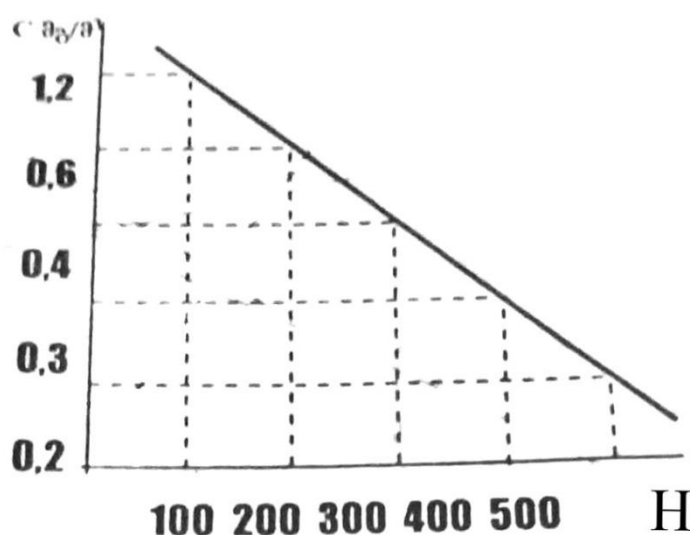
$$C_{\infty} = 2G_0 Z \rho H^2 B W_2$$

Where  
 $\rho = 1.2 \text{ kg/m}^3$ . COC is taken equal to the average of 2,  
 $H_0$  is the height above which the air can be considered conditionally clean  
 $H_0 = 100 + 500 \text{ m}$ .  
 $B$  – width of the city in meters (3000-5000)m  
 $W_x$  – average wind speed in m/s  
 $Co_z = 3 + 6 \text{ kg/min}$  for gases emitted from the energy sector.

The weight of combustion products is equal to  $Co_z = \rho \cdot 103 \text{ mg/m}^3$ .

According to the experimental data, the concentration measured at a height of 2 m in the city of Kutaisi is  $3.08 \text{ mg/m}^3$ , while the concentration obtained by the formula is  $2.82 \text{ mg/m}^3$ , with an error of 0.82%.

The data obtained by the formula at and above 100 m altitude are presented in the graph (Fig. 2).



The formula is fair for passive impurities, but it is not general. Further refinement of the formula requires consideration of other additional conditions.

### Conclusion

The existing model makes it possible to determine the dynamics of harmful substance transport. The model is significant because environmental pollution by impurities is one of the factors hindering sustainable environmental development. The development of a green economy contributes to improving environmental conditions and ensuring healthy living, supports the implementation of European standards and requirements in managing and implementing industrial processes, and fulfills the main requirement of sustainable development—significant improvement in the population's quality of life. The advantages of sustainable development principles and support for green economy development are emphasized in Georgia's current socio-economic strategic development plans.

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# ECONOMIC SCIENCES

## THE IMPACT OF THE IRAN WAR ON GEORGIA'S ECONOMY AND WAYS TO OVERCOME IT

**David Bidzinashvili**

*Doctor of Economics, Professor Gori State University, Georgia*

**Tsiskara Zarandia**

*Doctor of Economics, Professor Samtskhe-Javakheti State University, Georgia*

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### Abstract

Despite the geographical distance, the ongoing conflict in the Middle East has a significant impact on Georgia's economy. The consequences of the conflict are already becoming evident both in international markets and in Georgia's trade and financial relations.

It is particularly important to note that Georgia actively trades with countries that are directly or indirectly connected to the conflict zone, including Iran, the United Arab Emirates, and Saudi Arabia.

The total volume of imports from these countries amounts to hundreds of millions of dollars and includes such important products as construction materials, industrial polymers, machinery, and various consumer goods. Accordingly, logistical disruptions, risks to maritime routes, and potential supply constraints are directly reflected in the Georgian market, primarily in the form of rising prices and supply shortages.

**Keywords:** International market; Imports; Cargo flows; Middle Corridor; Tariff policy; International reserves; Foreign currency inflows.

**Intraduction:** The Middle East conflict presents both a challenge and a window of entirely new opportunities for Georgia. If instability in Iran continues, Georgia may be able to attract additional cargo flows. Opinions on this issue are divided—some believe that if the conflict persists, cargo flows will shift to Georgian territory, while others argue that the growth of cargo flows and the overall development of transport corridors in the region require peace and stability.

Against the backdrop of ongoing military operations in Iran, the disruption of the balance among regional transport corridors increases the strategic importance of the Middle Corridor and of Georgia itself.

Despite the existing uncertainty, the current developments create new opportunities for Georgia to attract additional cargo flows and strengthen its position as a regional logistics hub. These processes are less predictable, and at this stage, assessments may remain largely hypothetical. If we look at the development dynamics of the Middle Corridor, in 2022, due to military confrontation in the region, the volume of shipments passing through Georgia increased by 50%. This was a significant advancement; however, in the following years—2023, 2024, and 2025—this growth could not be sustained, and a certain declining trend was also observed. This indicates that Georgia was unable to fully capitalize on the existing window of economic opportunity.

**Reserchobjective:** The aim of this research paper is to study and analyze the impact of the intensified conflict in the Middle East (Iran–USA–Israel) on Georgia's economy, its associated challenges, and emerging opportunities; as well as to examine the potential for the relocation of cargo flows through Georgian territory, the growth of cargo volumes, the development of transport corridors in the Caucasus region, and the resulting opportunities for additional strategic significance for Georgia.

**Methology:** The theoretical and methodological foundation of the research is based on studies and scientific publications by both Georgian and foreign scholars, data from the National Bank of Georgia, the Ministry of Finance of Georgia, the National Statistics Office of Georgia, and social policy documents. An in-depth analysis of the existing data was conducted, and specific conclusions and recommendations were developed.

**Review and discussion:** Since February 28, 2026, developments surrounding Iran have caused fluctuations in global energy markets and temporary disruptions in regional airspace and maritime transport. Direct economic dependence on Iran is low. Georgia's direct economic ties with Iran are limited. In 2025, Iran accounted for only 0.9% of Georgia's total foreign currency inflows (including exports, tourism, foreign direct investment, and remittances) [1]. Furthermore, the 12-day conflict between Israel and Iran in 2025 did not have a noticeable macroeconomic impact on Georgia. This indicates that short-term and geographically limited escalations generally have a minimal effect on Georgia's economy.

In a scenario where the conflict lasts approximately one month, Georgia's GDP growth in 2026 would slow by only 0.2 percentage points from our baseline forecast of 6.0%. Inflationary effects are expected to remain moderate and largely transitory. If tensions ease and disruptions remain limited—as currently anticipated—the economic impact on Georgia will be minor and temporary[2].

Georgia's economic ties with Iran, Israel, and the countries of the Persian Gulf are moderate and concentrated in a few channels, particularly tourism. Direct economic links with Iran are quite limited. In 2025, Iran accounted for only 0.9% of Georgia's total foreign currency inflows[3]. Tourist revenues from Iran represented 2.6% of total tourism income, while exports of

goods to Iran accounted for just 0.5% of total exports[4]. Remittances and foreign direct investment from Iran are practically negligible. This indicates that short-term disruptions specifically related to Iran are unlikely to have a significant impact on Georgia's economy.

The economic effect of the conflict is further amplified by rising international energy prices. Higher oil prices increase transportation and logistics costs, which ultimately affect the prices of nearly all goods. This trend is particularly important against the backdrop of existing inflationary pressures in the country, especially in food products. As a result, the global shock adds an additional challenge to the local economic environment [5].

Georgia is a significant importer of energy resources. Energy imports amount to slightly over \$2 billion, representing approximately 11% of total imports. Therefore, any changes in energy markets directly affect the country's economy.

Due to the conflict and logistical challenges, the supply of certain products has already been restricted. For example, significant volumes of iron and various construction materials are imported from Iran, classified under commodity groups 72–73. The import value of these goods is approximately \$180 million. Packaging materials, widely used by Georgian companies across multiple sectors, are also important. A relatively smaller but still notable category is milk concentrates (milk powder), which are extensively used in production.

Before the conflict, oil prices fluctuated around \$70–73 per barrel. After the onset of the conflict, prices peaked at approximately \$119 per barrel. Prices later eased somewhat but currently remain around \$100 per barrel. Rising energy costs primarily increase transportation and logistics expenses, which ultimately affect the prices of various goods, including food products[6].

These developments coincided with a period when inflation in Georgia was already present. As of February, overall inflation was approximately 4.6%, while food prices had risen by around 9%. Under such conditions, rising energy prices create additional inflationary pressure.

Amid the redistribution of international transit routes, the so-called Middle Corridor—which connects Central Asia, the Caucasus, and Europe—gains increasing importance. Georgia's geographic location provides a significant strategic advantage in this process; however, realizing this potential largely depends

on the development of the country's transport and logistics infrastructure.

Despite existing risks, there are also potential positive effects. One of these is the growing importance of the Middle Corridor. The northern transit route through Russia is significantly limited, and other routes also face logistical challenges. As a result, the trans-Caspian route, encompassing Kazakhstan, Azerbaijan, and Georgia, becomes more significant, representing a potentially important economic opportunity for Georgia.

**Conclusion and Recommendations:** □ The key priority for Georgia is to maintain a balanced policy, ensure peace within the country, avoid provocations, and continue to uphold the neutrality that it has maintained so far. Regarding the potential increase in cargo volumes, Georgia has two main opportunities: first, a significant growth in cargo flows, since the country effectively connects Europe with the region; and second, energy resources. In practice, Europe is likely to become increasingly dependent on Georgia and its geographic location. The conflict in Iran could, therefore, provide an opportunity to enhance Georgia's strategic role.

- Beyond maintaining peace, the three Caucasus countries—Georgia, Azerbaijan, and Armenia—have no real alternative. The only way to ensure survival and stability is through close cooperation among all three countries, both politically and economically.

- If instability in Iran and the broader region continues, it will represent a severe blow to all countries in the region.

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## PROSPECTS FOR THE ROLE OF TOURISM IN NATIONAL ECONOMIC DEVELOPMENT IN AZERBAIJAN: THE LANKARAN–ASTARA REGION

**Tural Alakbarov**

*Assistant,*

*Azerbaijan Technological University*

**Ferman Isgenderov**

*Docent,*

*Azerbaijan Technological University*

**Fizuli Musayev**

*Lecturer,*

*Azerbaijan Technological University*

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### Abstract

This article investigates the role of tourism as a component of national economic development, specifically examining the southern regions of Azerbaijan. The primary objective of the research is to comprehensively analyze the tourism potential of the Lankaran-Astara economic region and identify its developmental prospects. The study indicates that the development of tourism positively impacts increasing employment, revitalizing the local economy, and improving infrastructure in the region. Simultaneously, existing challenges—such as infrastructure deficiencies, inconsistent service quality, and weak international promotion—have been identified, and proposals for addressing them have been put forward. Consequently, the development of tourism within the Lankaran-Astara economic region occupies a significant place in Azerbaijan's regional and national economic development strategy, and the sustainable growth of this sector holds substantial importance for future prospects.

**Keywords:** tourism, economic, development, regional, Lankaran–Astara economic region

**Introduction.** In the modern era, the tourism sector acts as a component of national economic development, playing a vital role in the socio-economic progress of nations. Particularly within the context of regional development, the role of tourism becomes increasingly relevant, as this field directly influences the efficient utilization of local resources, the increase of employment, and the development of infrastructure. From this perspective, studying the tourism potential of the regions in the Republic of Azerbaijan and involving them in economic turnover holds significant scientific and practical importance. The study presents tourism opportunities as a component of national economic development using the example of Azerbaijan's southern regions and investigates developmental prospects. Specifically, the Lankaran-Astara economic region was kept in focus due to its distinctive rich natural resources, favorable geographical position, and diversified tourism resources.

Located in southern Azerbaijan between the shores of the Caspian Sea and the Talysh Mountains, the Lankaran-Astara economic region possesses a favorable position from both natural and economic perspectives. The region's border with Iran and the passage of major international transport corridors through this area enhance its strategic importance. Historically established as a center of trade and culture, the city of Lankaran continues to serve as one of the region's primary tourism hubs today. (Schuhbert & Thees, 2020).

Research indicates that the region's tourism potential is multifaceted. This includes resort-recreational resources, national parks with rich biodiversity, mountain and waterfall landscapes, historical-cultural heritage sites, maritime tourism opportunities, as well as rural and agrotourism resources. Specifically, natural areas such as Hirkan National Park and Gizilagaj National

Park increase the region's international significance in terms of ecotourism.

Simultaneously, unique natural sites such as Yanar Bulag (Burning Spring), mountain villages in Lerik and Yardimli, historical monuments like the Lankaran Fortress, and recreation zones located on the Caspian coast ensure the diversity of the region's tourism product. Furthermore, traditional agricultural sectors such as tea and citrus farming create conditions for the development of agrotourism, while local festivals and cultural events facilitate the formation of ethnotourism.

Thus, the study conducted on the example of the Lankaran–Astara economic region determines that the tourism sector, while playing a vital role in the socio-economic development of the region, functions as a component of national economic development. The efficient utilization of the region's existing tourism potential and the application of sustainable development strategies can further strengthen its position in both domestic and international tourism markets in the future.

At the same time, unique natural objects such as Yanar Bulaq, mountain villages of Lerik and Yardimli, historical monuments like the Lankaran Fortress, as well as recreation zones located on the Caspian coast, ensure the diversity of the region's tourism product. Furthermore, traditional agricultural sectors such as tea and citrus farming create conditions for the development of agrotourism, while local festivals and cultural events facilitate the formation of ethnotourism.

Thus, as a result of the research conducted on the example of the Lankaran–Astara economic region, it is determined that the tourism sector, while playing an important role in the socio-economic development of the region, also functions as a component of national economic development. The efficient utilization of the region's existing tourism potential and the application of sustainable development strategies can further

strengthen its position in both the local and international tourism markets in the future.

Located in southern Azerbaijan, between the shores of the Caspian Sea and the foothills of the Talysh Mountains, the Lankaran-Astara economic region encompasses the administrative territories of Yardimli, Astara, Jalilabad, Lerik, Masalli, and Lankaran. Its position on the border with Iran and the passage of a major international transport route through this area grant the region strategic importance. As an ancient port city, Lankaran was historically surrounded by fortress walls and developed over many years as a trade center. The resort-recreational potential of the region is particularly noteworthy. The existence of nearly 20 mineral springs in the Astara district alone, along with the availability of therapeutic sea, sand, and sun baths in Lankaran, makes this area a significant destination for health tourism. Sanatoriums such as "Ibadi-Istisu" (Lankaran), "Istisu," "Gamo," and "Yanardag" (Masalli), as well as the "Meshabeyi" and "Relax" recreation complexes in Lerik, operate within the region. Təbii turizm ehtiyatları və milli parklar

One of the region's greatest advantages is its unique nature. In this regard:

Hirkan National Park – rich in rare relict and endemic plants, it encompasses the Hirkan forests included in the UNESCO list. It is favorable for ecotourism, trekking, and photo-tourism. Hirkan National Park is considered one of the most important natural assets of the region. This park was primarily established to protect Hirkan-type relict forests, where plant species dating back millions of years have been preserved to this day. Rare and endemic plants such as the ironwood (parrotia), chestnut-leaved oak, and Hirkan boxwood are widespread within the park's territory.

Furthermore, the area is distinguished by its rich fauna. Animals such as the Caucasian leopard, bear, lynx, and wild boar are found here. Hirkan National Park is highly conducive to ecotourism, facilitating activities such as trekking, scientific research tours, biodiversity studies, and photo-safaris. Its inclusion in the UNESCO World Heritage list further enhances the area's attractiveness for international tourism.

Gizilagaj National Park – one of the primary habitats for migratory birds, it holds special significance for ornithological tourism. Gizilagaj National Park is one of Azerbaijan's most important wetland ecosystems and is of great importance, particularly for ornithological tourism. This area is included in the Ramsar zone of international importance and serves as a wintering and nesting site for thousands of migratory birds.

Gizilagaj National Park creates extensive opportunities for ecological awareness, birdwatching, photography, and scientific research tourism. In this respect, it plays a vital role in diversifying the region's tourism product.

Yanar Bulag – is one of the rare natural phenomena where water ignites, serving as an intriguing attraction for tourists. Yanar Bulag is considered one of the most unique natural monuments in the region. The primary distinguishing characteristic of this spring is its ability to ignite due to the influence of natural gases contained within the water. When a flame is lit over the

spring, the water continues to burn, representing a natural occurrence rarely encountered globally.

This phenomenon generates significant interest for tourists from both scientific and visual perspectives. Especially in terms of ecotourism and geotourism, Yanar Bulag possesses the potential to become a tourism brand for the region. Tourists visiting the area can observe these extraordinary features of nature while enjoying the natural beauty of the surrounding villages.

The conducted research indicates that the Lankaran-Astara economic region, possessing a rich and diversified tourism potential, plays a vital role as a component of national economic development. The region's favorable geographical position, its location on the shores of the Caspian Sea, and its enclosure by the Talysh Mountains create conditions for the parallel development of various types of tourism. (Guliyev & Nuriyeva, 2017; Molan et al., 2021).

As a **result** of the research, it has been determined that the region's tourism resources are formed along the following directions:

- resort and health tourism (mineral springs, therapeutic climatic conditions)
- ecotourism and biodiversity (Hirkan National Park, Gizilagaj National Park)
- mountain and adventure tourism (territories of Lerik and Yardimli)
- historical-cultural tourism (Lankaran Fortress and other monuments)
- maritime tourism (Caspian shores)
- rural and agrotourism (tea farming, citrus farming, rural lifestyle)
- festival and ethnographic tourism

This diversity allows for the diversification of the tourism product in the region, the ensuring of year-round tourism activity, and the increase of economic revenues. Simultaneously, the tourism sector positively impacts the enhancement of employment, the development of infrastructure, and the improvement of the social welfare of local communities in the region.

However, during the study, it was identified that despite the existing potential, the development of the tourism sector in the region has not been fully realized. Infrastructure deficiencies, inconsistent service quality, weak international promotion, and limited investment opportunities restrict the development of this field to a certain extent.

**Proposals.** To utilize the region's tourism potential more efficiently and to strengthen its role as a component of national economic development, the implementation of the following measures is considered appropriate: modernization of road, transport, and communication systems, Increasing the number of hotels, recreation centers, and service facilities in the region, Improving accessibility for tourism in mountain and rural areas, expansion of ecological tourism routes within the territories of Hirkan National Park and Gizilagaj National Park, harmonization of tourism activities with the preservation of biodiversity, organization of ecological awareness programs, involvement of the local population in tourism activities, supporting

guesthouses and rural tourism enterprises, parallel development of health, adventure, cultural, and festival tourism directions promotion of unique sites such as Yanar Bulag as tourism brands.

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# JURISPRUDENCE

## CHILD RIGHTS AND CORRESPONDING COURT DISCUSSIONS OF PROBLEMATIC ISSUES

**Dali Chanidze**

*Doctoral student of law*

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### Abstract

The objective of the given article is the child rights national and international mechanisms full analysis, with the utmost stress upon Georgian legal base and court practice. The discussion refers to legislation of Georgia, European legislative systems, and child rights protection international acts, particularly, EU convention of human rights article 8 and UN convention article 12.

The research considers in detail difficulties of balancing parents' rights and child's best interests. Certain problematic issues are defined in legislative space of Georgia, amongst them, vacuum in the terminology of normative acts and the degree of court litigation on the child's legal decisions. Shortcomings of social services agencies work are described, family relations sphere, where legal, moral, and civil interests are closely intertwined, all of that demands close attention on the state's part.

Notwithstanding the fact that child rights are established in more than 150 legal acts, normative plenitude does not mean that there are no problems in implementation of these acts. In the paper existing drawbacks are stated and their eradication ways are suggested, amongst them, institutional reform and clarification of the legislation.

**Keywords:** child, rights, gradation, court practice, concept, best interests, social worker, ombudsman.

### 1. Introduction

Child rights are founded upon fundamental principles, which are adopted in many a country, on national as well as international level. Legal status of minors is defined by many acts/ proceedings, with the aim of child rights and interests protection and guaranteed preservation of their freedom.

In relation to child rights protection the problem is the absence of general court practice. In some countries, amongst them Georgia, notwithstanding the existence of "child rights law" in Georgia on the legal level issues of child rights protection are not legally regulated.

Extraordinarily problematic is the social services activity. There are no distinctly regulated, defined legal acts with regards to social services agencies workers, which would have helped to determine their rights-obligations in the process of child right protection.

Foreseeing the actuality of the abovementioned issues the main objective of our research is: discussion of different countries legislation, analysis of Civil Procedural law of Georgia, problematic regulation of the child rights legal protection and eradication of these problems.

### 2. Sources and Methods

The paper's main sources are: international conventions on child rights protection, legislation of foreign countries (in particular, of Germany) Child rights law of Georgia, reports of the public defender of Georgia, as well as, general courts of Georgia and European human rights court (ECHR) precedent legislation. To legally correctly define existing problematic issues, it is important to use court practice thoroughly. The court practice determines at present, how general courts of Georgia and foreign countries courts make decisions upon child rights protection issues and what shortcomings exist in that relation. Comparative legislation and practical leading cases analysis methods are used.

### 3. CIVIL PROCEDURAL PECULIARITIES IN FAMILY LITIGATION

In the courts of general jurisdiction civil cases management is regulated by civil procedural law, which defines family litigation discussion peculiarities. In relation to family lawsuits civil procedural law additional norms are used. It should be noted, that in relation to family cases, court has extraordinary discretionary rights. For example, while establishing child's domicile, the court can by its own initiative research the circumstances, proofs to which the parties have not pointed out to. By own initiative question the minor and correspondingly take into consideration his interests when establishing child's domicile.

In court practice a lawsuit about raising the child and establishing his domicile is possible without annulment of the marriage, when a party requests the court to establish child's domicile, but does not request to annul the marriage. But if annulment of the marriage and establishing child's domicile is requested the court does not separate two lawsuits consideration and examines it with marriage annulment. This principle is absolutely justified as marriage annulment is followed by nervous pressure and the court has the right to give the parties additional time for consideration. It is probable that in additional time given by court the parties make peace and there will be no need in establishing child's domicile.

In family lawsuits relation court's consideration of peculiarities also manifest in that that court by own initiative includes as a third party social service agency, as well as child psychologist, and it is precisely by social services agencies and by the psychologist's conclusion, and by taking into consideration child's best interests makes final decision.

Notwithstanding that court uses its own leverage in relation to family cases, there still exist shortcomings

on the legal level, eradication of which must be carried out by taking into consideration child's best interests.

#### 4. PROTECTION OF FAMILY LIFE BY EUROPEAN CONVENTION

According to article 8 of convention on human rights and freedom protection, everyone has a right to respect his own family life. State interference is prohibited except in cases when such interference is determined by law and is conditioned by national security of the democratic society, civil order, or other people's rights and freedoms protection necessity.

To realize the concept of "family life" it is necessary to denote that convention is a "live tool" which takes into consideration the necessity of value interpretation by the court of law articles and also taking into consideration of each social change. Each decision is taken individually by considering of every fact, existing relations and reality.

Children that were born in marriage, ipso jure are part of man and woman's relations; correspondingly after child's birth there ensues connection which equals family life. Parents should not necessarily live together. In case *Marckx v. Belgium*, the court decided that child and unmarried mother relations represent family life. But child and father of the same status relations do not automatically equal family life, which means that all aspects should be considered.

According to Constitutional court of Georgia, family life necessitates wide definition and means marriage or actual cohabitation of man and woman, human ability to establish connections with family members and biological relatives.<sup>1/1</sup> Kaladze S.-Turava P. Child Rights Law Guiding Comments, Tbilisi 2011, "The Lawyers' World" publishing house/But though family is represented as existing in marriage subject, this does not mean that children born out of wedlock are not entitled to same rights as a child born in marriage is.

The article 8 of family life statement provides its protection. In the case *Marckx v. Belgium*, the court stated that the state has a positive responsibility to realize such national legislation which will guarantee child's integration into family life. The positive responsibility doctrine demands member-states protect individuals from violation of the rights guaranteed by convention and help to fulfill these rights.

In the case *Johnston v. Ireland*, the court stated that unmarried parents and their children normal development of natural family relations demands that their state legally and socially equal state of a child of married parents.

#### 5. A RIGHT TO LISTEN TO THE CHILD AND CHALLENGES OF SOCIAL SERVICES

UN Convention article 8 clearly states: "When adults take decisions concerning children, children have a right to express their own view and this view should be taken into consideration." But consideration of child's view is often ineffective, while social workers sometimes form prejudiced evaluations, in connection with family relations.

The case of "N. TS. And others v. Georgia" (2016 3 Feb) in the European court is an example that consid-

ering child's interests and views in all court and administrative proceedings needs improvement. According to article 1200 subsection 2 of the civil law in this case child's interests must have been represented by social services agency. Although neither civil procedural law, nor legislation in connection with social services work define functions and powers of the appointed representative. The court decided that several reports by social services agency and presence at the hearings without having any power status was not to be considered as adequate and relevant representation.

ECHR stated that during any court hearings or administrative proceedings that influence child's rights (according to article 8) children who can form own view, must participate in the decision making process and must have an opportunity to be listened to and express their own view. (Sopo Kiladze-Paata Turava, "Guidelines for the Code of Rights of the Child, Commentary", Tbilisi 2021, Publishing House, "World of Lawyers".)

According to child rights law of Georgia article 8 a child have a right to be listened to during discussion of any issue which is connected to or will influence his rights, although for a child to express his view, it is necessary for him to be able to form that opinion. The child's ability to formulate his view is determined by his age and degree of maturity which in every case should be estimated carefully (L. Krappmann "The Weight of Child's view: Article 12 of the Convention of the Rights of a Child", 18 *International Journal of Children's Rights* (2010) p.507)

The existing drawbacks in Georgian court practice are:

- Social services do not provide courts with perfect conclusions with which parent it is better for a child to have a domicile
- It is not stated in court decisions why the court justifies child's best interests
- Social services agencies do not bring into life directives made by the court
- No conclusions of child psychologist are included in court decisions

#### 6. EXAMPLE OF GERMAN LAW

Unlike Georgian law Germany implemented full scale reform on child law. In 2000 article 1631 of the civil law was changed, according to which physical punishment and infliction of psychological traumas was forbidden when raising a child. German law admitted such notions as emotional violence and spiritual traumas. It was admitted that child's rights are superior to that of the parents.

According to German law a 14 years old child is an adolescent and he can already have his own views on different subjects, and in case of parents' divorce, his view on domicile is to be considered. Law of Germany protects child from any form of violence – scorn, abuse and mockery – child have a right to address police or social services to have parents arrested.

To provide high degree of child's rights protection it is important that Georgia joined the countries, that

legally forbid child's physical punishment. (Sospo Kladze-Paata Turava, „Guidelines for the Code of Rights of the Child, Commentary", Tbilisi 2021, Publishing House, „World of Lawyers".)

## 7. FINDING OF EVIDENCE AND CHILD REPRESENTATION

In order to define child's view, besides questioning him, it is necessary to appoint an examination of child's family situation, to identify parents' psychological peculiarities and child's psychological state. Unfortunately, Georgian law does not practice such procedure.

The most important problem in practicing the law is indefinite/ vague understanding of the question who must protect minor's lawful interests and rights. Unlike Russian Federation civil procedural law Georgian civil procedural law states that legal representatives of the minor are his parents, and in case of temporary suspension of parental rights legal representatives are Child Welfare Authorities.

According to Georgian law minor above 14 years of age has a right to address the court for protection of his rights and lawful interests. In such a case, the court appoints a procedural representative. Minor applicant in court has a right to disagree with his representative defend himself on his own. In such cases court has a responsibility to include Child Welfare Authorities.

In Georgian courts questioning of a child occurs in the presence of the lawful representative – a parent – when court has not psychologist's conclusion of how adequate the parent is, what degree of social responsibility the latter has and how he can influence the child during questioning. Correspondingly, the court must procure psychologist's conclusion on a parent as a proof and only after that decide whether the minor should be questioned in the presence of the parent or not.

## 8. BEST INTEREST AS THE MOST IMPORTANT CONCERN AND CHILD-ADJUSTED LAW

European court has frequently mentioned that in child – parents lawsuits, child's interest is of utmost importance, and can in its content and seriousness outweigh parents' interests. According to article 8 of the convention, a parent has no right to ask to implement such measures which may harm child's health and development.

This principle is reflected in article 1202 of the civil law of Georgia, which defines equal rights and responsibilities of divorced parents. According to article 1199 of the same law parents' rights should not be implemented in such a way so as to harm child's interests.

Child rights protection law of Georgia states that child has a right within any decision concerning him is taken he can make his best interests advantageous. If child's best interests are not given advantage then we have interference in child's rights. Still understanding of child's best interest needs deep and psychological approach. For example, a child wants to live with a parent who gives him much freedom, less control, and

does not want to stay where he is controlled over education, food, and relations. Correspondingly, in such case not child's wish is considered but his best interest which serves his education, upbringing, behavior control, to help him to become a good person.

In other words, child's welfare is what civil law tries to achieve, considering best interest is a means of achieving it. In wide sense, welfare is essential, material, physical, educational, emotional and safety need. (*Committee on the Rights of a Child, General Comments # 14 (2013) UN Doc CRC/GC/C 14, p.16*)

For a child to his view freely means that he should not be manipulated or coerced. Child has a right to express his views not the views of the others.

It is controversial and ought to be analyzed what should be considered child's best interests: only with which parent he wants to live or with a parent he will have better formation? Therefore, when establishing these facts courts must evaluate all the abovementioned factors.

## 9. FINDINGS AND RECOMMENDATIONS

Discussion in the paper clarifies, that Georgian legislation has no opportunity of clearly defining the notion of a minor: This concerns legal capacity, emancipation and other important issues.

## 10. LEGISLATIVE AND TERMINOLOGICAL IMPROVEMENT

Clarification of the notion of minor: It is necessary to separate notion of a minor and its gradation (e.g. below 0-7 years of age, 7-14 years of age, 14-18 years of age) as it is defined by German legislation, to regulate legal protection mechanism following specificity of age.

Legal capacity of the minor: Civil law must clarify whether a minor has legal capacity if he married.

## 11. INSTITUTIONAL STRENGTHENING

Child Ombudsman Institute: We think it is time to introduce child ombudsman institute and create its administrative apparatus (as it is in Germany, Finland, Denmark). This will help to concentrate problems in one concrete space and make process of child right protection more effective.

Regulation of Social Activity: Main principles of social work should strengthen and widen, also social workers rights and responsibilities. This will help guarantee child rights protection and for court to take objective decisions

## 12. PROCEDURAL and PRACTICAL RECOMMENDATIONS

Temporary orders: Before court issues temporary orders it is necessary for a judge to question minor, especially with regard to relations with parents.

Inclusion of experts and psychologists: It should become obligatory in court litigation concerning children to include child experts and psychologists. They can evaluate husband-wife relations in regard to family, which will help court determine correctly child's best interests, and better formation for the latter as a good person, while choosing domicile.

Protection of authors' rights" Corresponding legal acts should be adopted to protect especially gifted children author and creative rights (Tngland, Belgium and France's experience should be studied)

With the regulation of all abovementioned issues it will become possible to adopt relatively perfect and guaranteed legislation concerning child rights protection.

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# MATHEMATICAL SCIENCES

## VORTEX DYNAMICS OF A LEMNISCATE STRIP: GEOMETRY AND INVARIANTS

Milyute E.

Department of Mathematical Computer Science,  
Vilnius University, IRG "LITAVEM-3"

Milyus A.

IRG "LITAVEM-3", Vilnius, Lithuania

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### Abstract

This paper considers the dynamics of a two-dimensional incompressible inviscid fluid on a lemniscate strip embedded in  $\mathbb{R}^3$ . A formulation of the Euler equations in vorticity–streamfunction variables is derived using a differential-geometric framework. In contrast to non-orientable surfaces such as the Möbius strip, the lemniscate strip is orientable, which allows the introduction of a globally consistent area form and the treatment of vorticity as a true scalar. This leads to the standard structure of vortex dynamics equations and the preservation of the full set of dynamical invariants, including circulation along each boundary component, total vorticity, and the family of Casimir invariants. It is shown that the orientability of the surface ensures the preservation of the sign of vorticity under advection and eliminates topological effects associated with its inversion. As a result, vortex dynamics on the lemniscate strip is qualitatively similar to flows on cylindrical surfaces, despite the nontrivial embedding geometry. Boundary conditions, the role of the metric geometry, and the influence of the strip shape on the evolution of vortex structures are discussed. The results highlight the fundamental role of surface topology in determining conservation laws and the long-term dynamics of two-dimensional flows.

**Keywords:** vortex dynamics, lemniscate strip, orientable surfaces, Euler equations, incompressible fluid, vorticity, streamfunction, circulation, Casimir invariants, differential geometry, topological hydrodynamics

### 1. Introduction

We consider the dynamics of a two-dimensional incompressible inviscid fluid on a lemniscate strip embedded in  $\mathbb{R}^3$ . In contrast to the Möbius strip [1], the lemniscate strip is an orientable surface, which leads to fundamental differences in the structure of the governing equations and conservation laws. Geometrically, such a strip can be obtained as a closed band with a double twist (by  $2\pi$ ), or as a surface topologically equivalent to a cylinder but with a self-intersecting centerline in the shape of a lemniscate. The key property is the existence of a globally consistent orientation, that is, one can choose a continuous normal vector field  $\mathbf{N}(\xi, \theta)$  over the entire surface.

Let  $\mathcal{L}$  be a lemniscate strip with coordinates  $(\xi, \theta)$ , where  $\xi \in [-a, a]$  and  $\theta \in [0, 2\pi]$ . In contrast to the Möbius strip, here the standard periodicity holds:

$$\mathbf{N}(\xi, \theta + 2\pi) = \mathbf{N}(\xi, \theta), \quad (1)$$

without a change of sign or a reversal of the coordinate  $\xi$ . This reflects the *orientability of the surface*.

The Euler equations for an incompressible fluid on  $\mathcal{L}$  can be written in geometric form:

$$(\partial_t + \mathcal{L}_u)v = -d\left(p - \frac{1}{2}|\mathbf{u}|^2\right), \quad \text{div } \mathbf{u} = 0, \quad (2)$$

where  $\mathbf{u}$  is the velocity field,  $v(\mathbf{u}, \cdot)$  is the momentum 1-form, and  $g$  is the induced metric on the strip. Since the surface is orientable, there exists a globally defined area form:

$$\mu = |g|^{1/2} d\xi \wedge d\theta, \quad (3)$$

which does not change sign when the surface is traversed.

The vorticity is defined as the 2-form  $dv$ , and, unlike in the Möbius-strip case, can be uniquely represented by the scalar function  $\omega$ :

$$dv = \omega \mu. \quad (4)$$

Here,  $\omega$  is a true scalar rather than a pseudoscalar, since the orientation is globally fixed. This is the key distinction: the sign of the vorticity does not depend on the choice of local basis, as illustrated in Fig. 1 [2, 5].

From the Euler equations, it follows that the vorticity is transported:

$$(\partial_t + \mathcal{L}_u)v = 0, \quad (5)$$

that is, the vorticity is advected by the flow without change along particle trajectories.



Figure 1. Reconstruction of the lemniscate strips from [2, 5] via conformal mapping into three-dimensional space according to the lemniscate strip law of “planar” vortex filaments of an ellipsoidal vortex (a more detailed description of the lemniscate law is given in Chapter 4 of [2]); the twist of each strip is  $180^\circ$ .

We introduce the streamfunction  $\psi$ , defined by the relation

$$\iota_u \mu = -d\psi \quad (6)$$

For readers not yet familiar with the terminology of topological vortex dynamics, note that the streamfunction  $\psi$  determines the velocity via a “rotation”, that is, as the gradient

of the streamfunction rotated by  $90^\circ$ , which can be written as:

$$\mathbf{u} = \nabla^\perp \psi. \quad (7)$$

The velocity field then automatically satisfies the incompressibility condition, while the vorticity is expressed through the Laplacian:

$$\omega = \Delta \psi \quad (8)$$

Thus, the dynamics is described by the “vorticity–streamfunction” system

$$\partial_t \psi + \mathcal{J}(\psi, \omega) = 0, \quad \Delta \psi = \omega, \quad (9)$$

where  $\mathcal{J}(\psi, \omega)$  is Jacobian.

We now consider the boundary conditions. The lemniscate strip has two boundaries corresponding to  $\xi = \pm a$ . The no-normal-flow condition:

$$u^\xi(\pm a, \theta, t) = 0, \quad (10)$$

is equivalent to the statement that the streamfunction is constant on each boundary component:

$$\psi(\xi = a, \theta, t) = C_1(t), \quad \psi(\xi = -a, \theta, t) = C_2(t). \quad (11)$$

In contrast to the Möbius strip, these two functions are independent, since the boundary consists of two disconnected components.

The circulation is defined as the integral of the momentum 1-form along each boundary:

$$\Gamma_1 = \oint_{\xi=a} \nu, \quad \Gamma_2 = \oint_{\xi=-a} \nu, \quad \text{and} \quad \Gamma_1 = \Gamma_2, \quad (12)$$

From the Euler equations, the conservation of circulation follows:

$$d\Gamma_1/dt = 0, \quad d\Gamma_2/dt = 0. \quad (13)$$

Thus, two independent circulation invariants exist on the lemniscate strip, in contrast to a single one on the Möbius strip. Moreover, due to orientability, the vorticity can be integrated over the entire surface.

Moreover, due to orientability, the vorticity can be integrated over the entire surface:

$$\int_L \omega \mu,$$

and this integral is related to the circulation via Stokes’ theorem:

$$\int_L \omega \mu = \Gamma_1 = \Gamma_2 = \Gamma. \quad (14)$$

This is a fundamental property that is absent in the case of non-orientable surfaces. The Casimir invariants are also conserved:

$$C_f = \int_L f(\omega) \mu, \quad (15)$$

for arbitrary functions  $f$ , not only even ones as in the Möbius-strip case. In particular, the total vorticity as well as the energy are conserved:

$$E = \frac{1}{2} \int_L |\mathbf{u}|^2 \mu = -\frac{1}{2} \int_L \psi \omega \mu. \quad (16)$$

Physically, this means that when a vortex is transported along the lemniscate strip, its sign does not change, and the flow structure remains consistent with the global orientation. Vortex structures may interact across both branches of the lemniscate, but they do not undergo the topological “flip” characteristic of the Möbius strip.

Thus, the orientability of the lemniscate strip leads to the conservation of total vorticity, the existence of two independent circulations, and a standard structure of invariants analogous to that on cylindrical surfaces, despite the non-trivial embedding geometry.

## 2. Momentum and incompressibility equations for the lemniscate strip

The momentum and incompressibility equations for the lemniscate strip have the same geometric form as for any oriented two-dimensional surface with an induced metric. Let  $\mathbf{u}$  be the velocity field,  $\nu = g(\mathbf{u}, \cdot)$  the corresponding momentum 1-form,  $g$  the metric tensor on the strip, and  $p$  the pressure. Then the momentum equation can be written as

$$(\partial_t + \mathcal{L}_u)\nu = -d\left(p - \frac{1}{2}|\mathbf{u}|^2\right) \quad (17)$$

while the incompressibility condition takes the form:

$$\text{div } \mathbf{u} = 0. \quad (18)$$

If we introduce local coordinates  $(\xi, \theta)$  on the lemniscate strip and write the velocity in the form

$$\mathbf{u} = u^\xi \partial_\xi + u^\theta \partial_\theta, \quad (19)$$

then for a diagonal metric

$$g = g_{\xi\xi} d\xi \otimes d\xi + g_{\theta\theta} d\theta \otimes d\theta \quad (20)$$

and choosing a parametrization such that  $g_{\xi\xi} = 1$ , we obtain

$$\nu = u^\xi d\xi + |g| u^\theta d\theta, \quad (21)$$

where  $|g| = \det g = g_{\theta\theta}$ . The momentum equation then splits into two coordinate components:

$$\begin{aligned} (\partial_t + u^\xi \partial_\xi + u^\theta \partial_\theta) u^\xi - \frac{1}{2} (u^\theta)^2 \partial_\xi |g| &= -\partial_\xi p, \\ (\partial_t + u^\xi \partial_\xi + u^\theta \partial_\theta) (|g| u^\theta) - \frac{1}{2} (u^\theta)^2 \partial_\theta |g| &= -\partial_\theta p \end{aligned} \quad (22)$$

The incompressibility condition in these coordinates is written as

$$|g|^{-1/2} \left( \partial_\xi (|g|^{1/2} u^\xi) + \partial_\theta (|g|^{1/2} u^\theta) \right) = 0. \quad (23)$$

Since the lemniscate strip is orientable (1), the area form

$$\mu = |g|^{1/2} d\xi \wedge d\theta \quad (24)$$

is globally defined and does not change sign when the surface is traversed. Therefore, all quantities in these equations are standard geometric objects without the pseudoscalar corrections characteristic of the Möbius strip.

## 3. Velocity on the lemniscate strip

The velocity on the lemniscate strip is conveniently expressed in terms of the streamfunction  $\psi$ , since the strip is orientable and the area form (24) is globally defined. If  $\mathbf{u}$  satisfies (19), then from relation (6) we obtain the velocity components

$$u^\xi = -|g|^{-1/2} \partial_\theta \psi, \quad u^\theta = |g|^{-1/2} \partial_\xi \psi. \quad (25)$$

Therefore, the velocity field can be written as

$$\mathbf{u} = -|g|^{-1/2} \partial_\theta \psi \partial_\xi + |g|^{-1/2} \partial_\xi \psi \partial_\theta \quad (26)$$

This representation automatically satisfies the *incompressibility condition*

$$|g|^{-1/2} \left( \partial_\xi (|g|^{1/2} u^\xi) + \partial_\theta (|g|^{1/2} u^\theta) \right) = 0. \quad (27)$$

The corresponding momentum 1-form is given by

$$\nu = g(\mathbf{u}, \cdot) = u^\xi d\xi + |g| u^\theta d\theta \quad (28)$$

and hence

$$\nu = -|g|^{-1/2} \partial_\theta \psi d\xi + |g|^{1/2} \partial_\xi \psi d\theta \quad (29)$$

If the metric of the lemniscate strip is not diagonal, the general expression for the velocity in terms of the streamfunction is

$$u^\alpha = \mu^{\alpha\beta} \partial_\beta \psi, \quad (30)$$

where  $\mu^{\alpha\beta} = |g|^{-1/2} \varepsilon^{\alpha\beta}$ , and in the diagonal case this reduces to

$$u^\xi = -|g|^{-1/2} \partial_\theta \psi, \quad u^\theta = |g|^{-1/2} \partial_\xi \psi \quad (31)$$

### 3. Vorticity–streamfunction formulation for the lemniscate strip

The full vorticity–streamfunction system for the lemniscate strip  $\mathcal{L}$ , as an orientable surface, is constructed in the standard way without the appearance of pseudoscalar quantities. Let  $u$  be the velocity field,  $v = g(u, \cdot)$  the momentum 1-form, and let the area form  $\mu$  given by (24) be globally defined. The vorticity is defined as the 2-form  $dv$ , which can be uniquely represented by a scalar function  $\omega$  via Eq. (4), so that  $\omega$  is a true scalar due to the orientability of the surface (1). From the momentum equation, it follows that the vorticity is transported by the flow:

$$(\partial_t + \mathcal{L}_u)\omega = 0 \quad (32)$$

In coordinates  $(\xi, \theta)$ , this gives the vorticity advection (transport) equation which also is equivalent to equation  $(\partial_t + u \cdot \nabla)\omega = 0$  (32\*):

$$\partial_t \omega + u^\xi \partial_\xi \omega + u^\theta \partial_\theta \omega = 0. \quad (33)$$

The velocity is expressed in terms of the streamfunction via (31), which automatically satisfies the incompressibility condition. Substituting this into the advection equation yields the vorticity equation

$$\partial_t \omega + |g|^{-1/2} (\partial_\xi \psi \partial_\theta \omega - \partial_\theta \psi \partial_\xi \omega) = 0. \quad (34)$$

The relation between vorticity and streamfunction is given by the Poisson equation on the surface  $\omega = \Delta \psi$  (8), where the Laplacian takes the form

$$\Delta \psi = |g|^{-1/2} (\partial_\xi (|g|^{-1/2} \partial_\xi \psi) + \partial_\theta (|g|^{-1/2} \partial_\theta \psi)) \quad (35)$$

Thus, the vorticity–streamfunction system on the lemniscate strip is written as

$$\partial_t \omega + |g|^{-1/2} \partial(\psi, \omega) = 0, \quad \Delta \psi = \omega, \quad (36)$$

where  $\partial(\psi, \omega) = \partial_\xi \psi \partial_\theta \omega - \partial_\theta \psi \partial_\xi \omega$ . (37)

The boundary conditions are determined by the fact that the strip has two boundary components  $\xi = \pm a$ , and the no-normal-flow condition  $(u \cdot n = 0)$  implies

$$\psi(\xi = a, \theta, t) = C_1(t), \quad \psi(\xi = -a, \theta, t) = C_2(t), \quad (38)$$

where the functions  $C_1(t)$  and  $C_2(t)$  are determined by the conservation of circulation along the boundary. Unlike the non-orientable case, the total vorticity integral is conserved:

$$W = \int_{\mathcal{L}} \omega \mu \quad (39)$$

and the standard Stokes relation between vorticity and circulation holds, which closes the system in the usual form of two-dimensional hydrodynamics on an orientable surface.

### 4. Intensity of the lemniscate strip

The intensity of the lemniscate strip in the context of hydrodynamics is naturally identified with the circulation or the total vorticity of the flow on the surface. Since the lemniscate strip is orientable, the vorticity is a true scalar and can be integrated over the entire surface. Therefore, the intensity is defined by the integral

$$W = \int_{\mathcal{L}} \omega \mu = \int_{-a}^a \int_0^{2\pi} \omega(\xi, \theta) |g|^{1/2} d\xi d\theta, \quad (40)$$

where  $\mu$  is the area form (8), and  $|g|$  is the determinant of the metric. By virtue of the Euler equations and incompressibility, this quantity is conserved in time and is related to the circulation along the boundary via Stokes' theorem:

$$W = \int_{\mathcal{L}} dv = \oint_{\partial \mathcal{L}} v = \Gamma, \quad (41)$$

Thus, the intensity  $W$  of the lemniscate strip coincides with the circulation along its boundary and is an invariant of the motion. Moreover, more general integrals of the form

$$C_f = \int_{\mathcal{L}} f(\omega) \mu \quad (42)$$

are also conserved, which implies that the distribution of vorticity intensity over the surface evolves without changing its integral characteristics. In contrast to the Möbius strip, here the intensity is uniquely defined, does not change sign when traversing the surface, and obeys the standard conservation laws of two-dimensional hydrodynamics.

### 5. Which strip is more stable: the lemniscate strip or the Möbius strip?

From a strict physical and dynamical perspective, the lemniscate strip proves to be more “robust.” This is because the lemniscate strip is orientable, which endows it with the full set of conservation laws characteristic of two-dimensional hydrodynamics. In particular, the total vorticity  $W$  (39) is conserved, as well as all Casimir invariants of the form  $\int f(\omega) \mu$ , and the circulations along each boundary component are conserved independently. This implies that the structure of the vorticity field is stable: vortices retain their “identity,” do not change sign, and evolve in a more predictable manner. Turbulence develops in the classical way, with an inverse energy cascade and the long-lived persistence of large-scale vortices.

On the Möbius strip, the situation is fundamentally different. Due to non-orientability, vorticity is a pseudoscalar and changes sign when the strip is traversed. As a result, the total vorticity integral is not defined, and only even functions of  $\omega$  are conserved [1]. Moreover, when a vortex is transported along the strip, its rotation is reversed, which destroys coherent structures. Thus, the reduction in the number of invariants leads to accelerated breakdown of vortex structures and the onset of chaotic advection.

On the lemniscate strip, the flow is consistent with the global orientation of the surface, whereas on the Möbius strip an inversion occurs due to its non-orientability. Therefore, from the perspective of flow structure preservation, vortex stability, and the number of dynamical invariants, the lemniscate strip is more stable (more “robust”) [2, 4-5], while the Möbius strip is more chaotic and more destructive to vortex structures.

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## A CHARACTERIZATION OF GEODETIC GRAPHS IN TERMS OF THEIR EMBEDDED EVEN GRAPHS

Frasser C.E.

*Ph.D. in Engineering Sciences, Odessa National Polytechnic University, Ukraine*DOI: [10.5281/zenodo.19483150](https://doi.org/10.5281/zenodo.19483150)

### Abstract

The problem of finding the general classification of geodetic graphs is still open. We believe that one of the obstacles to attain this goal is that geodetic graphs lack a structural description. In other words, their fundamental properties have not yet been established in terms of the description of the complete graphs, paths and cycles contained within them. The absence of this information makes their generation and enumeration (as inherent parts of their general classification) a difficult task. This paper examines the structural qualities of geodetic graphs using their so-called embedded even graphs. To this effect, the necessary and sufficient conditions for eliminating the nongeodecity of each pair of  $C$ -opposite vertices in an even cycle  $C$  have been formulated, while the bigeodecity of the embedded even graphs of a geodetic graph has been established. In a sense, this allows us to arrive at the conclusion that the basic building blocks of geodetic graphs are precisely this class of bigeodetic ones.

**Keywords.** Characterization, classification, embedded even graphs, geodetic graphs, bigeodetic graphs.

### Introduction

When beginning the design process of a computer network, the total set of information sources, the set of users, and the pairwise distances between them are generally known. Information sources include complex knowledge bases, encompassing databases and specialized software, which store enormous amounts of information. This information is accessed using specific computerized methods. Information users may include specific organizations and entities that possess the necessary technical means to connect to the network. The information obtained, after processing and analysis, is organized into a complex knowledge base. Interaction between these knowledge bases is established through transmission channels, which must be organized to maximize the information transmission speed. Clearly, this condition is met only when each pair of network centers is connected by a transmission channel. If we assign to each information center a vertex of an undirected graph, whose edges correspond to the transmission channels, then we obtain a complete graph, which, in fact, is a geodetic one. Using this connection arrangement between information centers minimizes the time required for information transmission, which is equivalent to maximizing information transmission speed. However, as the number of centers increases, the material costs for creating the network also increase, and in this case, the structure of a complete graph is no longer convenient [3]. It is evident that the construction of a geodetic network of the smallest possible diameter will be preferable. This network contains embedded even graphs with a special structure whose description we study next as an attempt to characterize geodetic graphs from a different perspective. We think, this could contribute to have a better understanding of how to solve the open problem of finding the general classification of geodetic graphs [2].

the two paths of equal length that make up the cycle. From a network perspective, an even cycle leads to the duplication of information transmission channels. If a high level of network reliability is required [3], then such a structure may be the most suitable. However, if minimizing network setup costs while maintaining a high data transmission speed is necessary, then such a structure is not appropriate. It is possible to eliminate the duplication of transmission channels by introducing a system of chords into the even cycle, whose result is what we call an *embedded even graph*. In order to describe the fundamental properties of embedded even graphs in a geodetic graph, we need to introduce some fundamental concepts.

The set of *vertices* and *edges* of a graph  $G$  are denoted by  $V(G)$  and  $E(G)$ , respectively. A *path* from  $v_0$  to  $v_n$  is a sequence  $v_0 v_1 \dots v_n$  of different vertices of  $G$  and is denoted by  $P(v_0, v_n)$ . The *number* of edges of a path  $P$  in  $G$  determines the *length* of this path and is represented by  $|P|$ . A graph  $G$  is *connected* if there exists a path in  $G$  between any pair of its vertices. The *distance* between  $u, v \in V(G)$ , denoted by  $d_G(u, v)$ , is the length of the shortest path connecting vertices  $u, v$ . The *diameter* of  $G$ , denoted  $d(G)$ , is the greatest distance between any pair of its vertices. The number of edges incident to a vertex  $v$  of  $G$  is called the *degree* of  $v$  and is denoted by  $\deg(v)$ . In a graph  $G$ , any vertex  $v$  having  $\deg(v) \geq 3$  is called a *node*. A *segment* is a path whose only nodes are its end vertices  $u$  and  $v$ . Two graphs  $G_1$  and  $G_2$  are said to be *homeomorphic* if and only if there exists a graph which can be obtained by insertion of vertices onto the edges of one or both of  $G_1$  and  $G_2$ . Note that any connected graph is homeomorphic to itself. A *complete graph* is a graph in which every pair of vertices are joined by an edge. The complete graph with  $n$  vertices is denoted by  $K_n$ . A *cycle* is a sequence  $v_0 v_1 \dots v_n v_0$  of different vertices of  $G$ . A cycle  $C$  of  $G$  is called *even* (*odd*) if its length  $|C|$  is even (odd). Assume that  $C$  is even. If  $u, v \in V(C)$ ,  $u \neq v$ , then there exist exactly two paths belonging to  $C$  joining vertices  $u$  and  $v$ . One of these paths is denoted by

### On some Structural Properties of Geodetic Graphs

In an even cycle, any pair of diametrically opposite vertices are joined by two geodesics determined by

$C(u, v)$ , and the other,  $C(v, u)$ . Two vertices  $x, y$  of an even cycle  $C$  are called  $C$ -opposite if  $|C(x, y)| = |C(y, x)|$ . A path  $A(u, v)$  joining no more than two vertices  $u, v$  of a cycle  $C$  is called a *chord* if  $|A(u, v)| < |C(u, v)|$  and  $|A(u, v)| < |C(v, u)|$ . A *subgraph*  $H$  of a graph  $G$  is a graph whose vertices and edges are subsets of those of  $G$ . The shortest path  $\Gamma(u, v)$  joining the vertices  $u, v$  of  $G$  is called a *geodesic*. A graph  $G$  is *geodetic* if there exists a unique geodesic between every pair of its vertices. A graph  $G$  is called  $K$ -geodetic if between each pair of its vertices there are, at most,  $K$  distinct geodesics. A  $K$ -geodetic graph is geodetic if  $K = 1$ , bigeodetic if  $K = 2$  and trigedetic if  $K = 3$ .

**Lemma 1.** ([5]) *A connected graph  $G$  is geodetic if and only if  $G$  does not contain an even cycle  $C$  such that for every pair of  $C$ -opposite vertices  $u, v$   $d_G(u, v) = d(C)$ .* □

**Theorem 1.** ([4]) *Let  $G$  be homeomorphic to the complete graph  $K_4$ ;  $G$  is geodetic if and only if:*

1. *The six segments of  $G$  are geodesics.*
2. *Each cycle of  $G$  that contains exactly three segments is odd.*
3. *All cycles of  $G$  that contain exactly four segments have equal length.* □

Let  $H$  be the graph obtained as a result of the union of an even cycle  $C$  that does not cut itself and a set of  $n$  vertex-disjoint chords  $A_1 = A(x_1, x_{n+1}), A_2 = A(x_2, x_{n+2}), \dots, A_n = A(x_n, x_{2n})$ , whose end vertices correspond to the pairs  $(x_1, x_{n+1}), (x_2, x_{n+2}), \dots, (x_n, x_{2n})$ , where  $x_1, x_2, \dots, x_n, x_{n+1}, x_{n+2}, \dots, x_{2n}$  is a successive cyclic labeling of the degree-three vertices (nodes) of  $H$  in the clockwise direction, which begins at some arbitrarily chosen node. We then define an *arc*  $C(u, v)$  in  $H$  as the path formed by the vertices and edges of the even cycle  $C$  joining two nodes  $u$  and  $v$  of  $H$ . We denote by  $|C(x, y)|$  the length of the shortest path in  $C$  joining any two arbitrary vertices  $x$  and  $y$  of  $C$ . This is also valid in the case where  $C(x, y)$  is an arc. Two chords  $A$  and  $B$  of  $H$  are said to be *adjacent* if, in the arcs of the even cycle  $C$  subtended by the end vertices of these chords, there are no end vertices of other chords. The cycles generated by a pair of adjacent chords and their corresponding subtended arcs have a length that we will designate as follows:

$$|C_i^j| = |C(x_i, x_j)| + |A(x_i, x_{n+i})| + |A(x_j, x_{n+j})| + |C(x_{n+i}, x_{n+j})|,$$

for  $i = 1, \dots, n$ , where  $x_i, x_j$  are two consecutive nodes of  $H$ , with  $j > i$  for  $i \leq n - 1$  and  $j = 1$  for  $i = n$ .

An embedded even graph  $H$  of a geodetic graph  $G$  containing a minimal even cycle  $C$  is a subgraph  $H$  of  $G$  obtained by combining the even cycle  $C$  and its chord system (in the sense explained above) such that in  $H$  no pair of adjacent chords and the subtended arcs of  $C$ , or

chord and arc, form an even cycle of length less than  $|C|$ .

Based on the concepts previously described, our main theorem follows.

**Theorem 2.** *Let  $H$  be an embedded even graph that has a system of  $n$  vertex-disjoint chords and whose even cycle  $C$  has length  $2L$  for any integer  $L \geq 2$ , where  $2 \leq n \leq L$ . The chord system of  $H$  eliminates the nongeodeticity of all pairs of  $C$ -opposite vertices and preserves the geodeticity of all pairs of non- $C$ -opposite vertices if and only if the following conditions are met in  $H$ :*

1. *Every cycle consisting of an arc and a chord has odd length,*
2.  $|C_1^2| = |C_2^3| = |C_3^4| = \dots = |C_{n-1}^n| = |C_n^1| = |C| = 2L$

*Proof.* Necessity will be carried out by contradiction.

*Case 1.* Suppose there exists an embedded even graph  $H$ , whose chord system eliminates the nongeodeticity of all pairs of  $C$ -opposite vertices and preserves the geodeticity of all pairs of non- $C$ -opposite vertices, in which condition 2 satisfies, but in which there exists at least one even cycle  $C^*$  formed by the arc  $C(x_i, x_{n+i})$  or the arc  $C(x_{n+i}, x_i)$  and a chord  $A_i$ , for some  $i = 1, \dots, n$ . Then  $C^*$  in  $H$  is an even cycle of length less than  $2L$  formed by an arc of cycle  $C$  and a chord. But this contradicts the definition of  $H$  being an embedded even graph.

*Case 2.* Let us now suppose that there exists an embedded even graph  $H$ , whose chord system eliminates the non-geodeticity of all pairs of  $C$ -opposite vertices and preserves the geodeticity of all pairs of non- $C$ -opposite vertices, in which condition 1 satisfies, but in which there exist even cycles  $C_i^j$  such that  $|C_i^j| \neq 2L$ . If for some pair  $i, j$ ,  $|C_i^j| < 2L$ , then  $H$  contains a pair of adjacent chords with their respective subtended arcs, which form an even cycle of length less than  $|C|$ . This contradicts the definition of  $H$ . Therefore, suppose that  $|C_i^j| > 2L$ . Let us examine one of the cycles  $C_i^j$ . Without loss of generality, suppose that  $C_i^j$  is the cycle  $C_1^2$  (Fig. 1).

Let us select in  $H$  the vertex  $v \in C, v \in C_1^2$  that lies on the odd cycle formed by the arc  $C(x_1, x_{n+1})$  and the chord  $A_1 = A(x_1, x_{n+1})$  such that

$$|C(v, x_{n+1})| = |A_1| + |C(x_1, v)| - 1 \quad (1)$$

Select now vertex  $u$  so that  $u$  and  $v$  are  $C_1^2$ -opposite vertices and, at the same time, are  $C$ -opposite vertices in  $H$ . Then

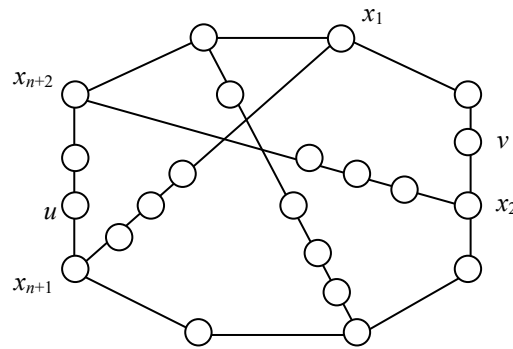


Fig. 1.

$$|C(u, x_{n+1})| + |C(x_{n+1}, v)| = L,$$

that is,

$$|C(x_{n+1}, v)| = L - |C(u, x_{n+1})| \quad (2)$$

Equating (1) to (2), we obtain

$$|A_1| + |C(x_1, v)| - 1 = L - |C(u, x_{n+1})|,$$

which means that

$$|C(u, x_{n+1})| + |A_1| + |C(x_1, v)| = L + 1. \quad (3)$$

Since  $|C_1^2| > 2L$ , that is,  $|C_1^2| \geq 2L + 1$  and  $|C(u, x_{n+1})| + |A_1| + |C(x_1, v)| = L + 1$ ,

$$|C(v, x_2)| + |A_2| + |C(x_{n+2}, u)| \geq L. \quad (4)$$

Knowing that in  $H$ ,  $|\Gamma(u, v)|$  has to be less than or equal to  $L - 1$ , correlations (3) and (4) imply that the only geodesic  $\Gamma(u, v)$  does not lie on  $C_1^2$ . But it does not lie on  $C$  either because  $u$  and  $v$  are  $C$ -opposite vertices. Considered now the cycle  $C^*$  formed by the chord  $A_1$ , one of the chords  $A_j$ ,  $j = n, n - 1, \dots, 3$  and the arcs subtended by them. Note that  $|C^*| \geq 2L$ . It follows that for the only geodesic  $\Gamma(u, v)$  (Fig. 1)

$$|\Gamma(u, v)| = |C^*| - |A_1| + |C(x_1, v)| + |C(u, x_{n+1})| \leq L - 1,$$

which is equivalent to

$$|C^*| \leq |A_1| - |C(x_1, v)| - |C(u, x_{n+1})| + L - 1$$

$$|C^*| \leq 2|A_1| - (|A_1| + |C(x_1, v)| + |C(u, x_{n+1})|) + L - 1. \quad (5)$$

Substituting (3) into (5), we obtain

$$|C^*| \leq 2|A_1| - L - 1 + L - 1$$

$$2L \leq |C^*| \leq 2|A_1| - 2$$

$$L \leq |A_1| - 1 < |A_1|$$

$$L < |A_1|,$$

which means that the length of a chord is greater than the length of any of the two corresponding arcs on  $C$ . This contradicts the above definition of a chord.

Lastly, consider the cycle  $C^{**}$  formed by the chord  $A_2$  one of the chords  $A_j$ ,  $j = 3, 4, \dots, n$  and the arcs subtended by them. In this case,

$$|\Gamma(u, v)| = |C^{**}| - |A_2| + |C(v, x_2)| + |C(x_{n+2}, u)| \leq L - 1$$

$$|C^{**}| \leq |A_2| - |C(v, x_2)| - |C(x_{n+2}, u)| + L - 1.$$

$$|C^{**}| \leq 2|A_2| - (|A_2| + |C(v, x_2)| + |C(x_{n+2}, u)|) + L - 1 \quad (6)$$

From (4) and (6), we now obtain

$$\begin{aligned} 2L \leq |C^{**}| &\leq 2|A_2| \\ &\quad - (|A_2| + |C(v, x_2)| \\ &\quad + |C(x_{n+2}, u)|) + L - 1 \\ &\leq 2|A_2| - L + L - 1 \end{aligned}$$

$$2L \leq 2|A_2| - 1 < 2|A_2|$$

$$L < |A_2|,$$

which is again a contradiction.

From all of the above, we conclude that the geodesic  $\Gamma(u, v)$  lies either on  $C$ ,  $C_1^2$ , or both.

Since according to (4)  $|C(v, x_2)| + |A_2| + |C(x_{n+2}, u)| \geq L$ , either  $|C(v, x_2)| + |A_2| + |C(x_{n+2}, u)| = L$  or  $|C(v, x_2)| + |A_2| + |C(x_{n+2}, u)| > L$ .

If  $|C(v, x_2)| + |A_2| + |C(x_{n+2}, u)| = L$ , then  $H$  contains three geodesics  $\Gamma(u, v)$  of length  $L$ : one is contained in  $C_1^2$  and the other two in  $C$ . This contradicts our assumption.

If  $|C(v, x_2)| + |A_2| + |C(x_{n+2}, u)| > L$ , then  $H$  contains two geodesics  $\Gamma(u, v)$  of length  $L$ , both contained in  $C$ , which again contradicts our assumption.

No contradictions arise only in the case when

$$|C(v, x_2)| + |A_2| + |C(x_{n+2}, u)| = L - 1$$

In this case, the pair of adjacent chords  $A_1, A_2$  and their subtended arcs form a cycle in which  $H$  has a unique geodesic  $\Gamma(u, v)$  of length  $L - 1$  and

$$\begin{aligned} C_1^2 &= (|C(u, x_{n+1})| + |A_1| + |C(x_1, v)|) \\ &\quad + (|C(v, x_2)| + |A_2| \\ &\quad + |C(x_{n+2}, u)|) \\ &= (L + 1) + (L - 1) = 2L. \end{aligned}$$

The same reasoning can be extended to any cycle  $C_i^j$ . So, we conclude that

$$|C_1^2| = |C_2^3| = |C_3^4| = \dots = |C_{n-1}^n| = |C_n^1| = |C| = 2L$$

Let us now prove *sufficiency*.

Assume that  $H$  satisfies conditions 1 and 2 of Theorem 2.

*Case 1.* If two  $C$ -opposite vertices  $u$  and  $v$  of  $H$  are the end vertices of the chord  $A_j$ , for a given  $j$ , then  $d_H(u, v) = |A_j| < L$  and the chord  $A_j$  is the only geodesic in  $H$ .

*Case 2.* Let  $u, v$  be  $C$ -opposite vertices that are not, at the same time, the end vertices of the chord  $A_j$ , where

$u, v \in C_j^{j+1}$ . If  $u$  and  $v$  are not  $C_j^{j+1}$ -opposite vertices, then, taking into account condition 2, that is,  $C_j^{j+1} = 2L$ , we conclude that  $d_H(u, v) < L$  and the only geodesic  $\Gamma(u, v)$  lies on  $C_j^{j+1}$ . If  $u$  and  $v$  are  $C_j^{j+1}$ -opposite vertices (Fig. 2), then let  $C_j^{j+1} = C_1^2$ . We then obtain

$$\begin{aligned} |C(v, x_1)| + |A_1| + |C(x_{n+1}, u)| &= \\ |C(u, x_{n+2})| + |A_2| + |C(x_2, v)| &= L; \end{aligned}$$

this implies that

$$|C(v, x_1)| + |A_1| = L - |C(x_{n+1}, u)|. \quad (7)$$

At the same time,

$$\begin{aligned} |C(v, x_{n+1})| + |C(x_{n+1}, u)| &= |C(u, x_1)| + \\ |C(x_1, v)| &= L; \end{aligned}$$

this implies that

$$|C(v, x_{n+1})| = L - |C(x_{n+1}, u)|. \quad (8)$$

Equating (7) to (8), we now get

$$|C(v, x_{n+1})| = |C(v, x_1)| + |A_1|,$$

that is, the chord  $A_1$  and the arc  $C(x_1, x_{n+1})$  form an even cycle of length less than  $|C| = 2L$ , which contradicts condition 1.

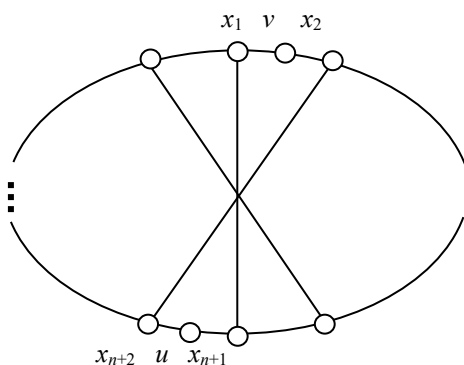


Fig. 2.

*Case 3.* If  $u, v$  are  $C$ -opposite vertices in  $G$  that do not belong to any of the cycles  $C_1^2, C_2^3, \dots, C_{n-1}^n, C_n^1$ , then both  $u$  and  $v$  belong to one of the cycles formed by an arc of the cycle  $C$  and a chord. Since this odd cycle has a length less than  $2L$ , then  $d_H(u, v) < L$ . Consequently, for the even cycle  $C$  and any pair of its  $C$ -opposite vertices  $u$  and  $v$ , we obtained that  $d_H(u, v) < d(C)$  and the proof follows immediately from Lemma 1.

**Corollary 1.** *If the embedded even graph  $H$  of Theorem 2 has  $n = 2$  chords, then  $H$  is geodetic.*

*Proof.* Clearly, when  $n = 2$ ,  $H$  is homeomorphic to the complete graph  $K_4$ .

i)  $C_1^2, C_2^1, C$  all contain exactly four segments. Condition 2 of Theorem 2 guarantees that  $|C_1^2| = |C_2^1| = |C|$ , that is, the three cycles containing four segments have equal length and condition 3 of Theorem 1 follows.

ii) The cycles obtained as a result of joining a chord and its two corresponding arcs each contains exactly three segments. Condition 1 of Theorem 2 guarantees that all of them are odd. So, condition 2 of Theorem 1 also follows.

iii) Statements i) and ii) imply, by Theorem 2, that the four segments lying on  $C$  are all geodesics. The other 2 segments are the chords  $A_1$  and  $A_2$ . But  $|A_1| < L$  and  $|A_2| < L$ . This means that both of them are geodesics in  $H$ . Consequently, the six segments of  $G$  are geodesics. Condition 1 of Theorem 1 follows as well.

Therefore,  $H$  satisfies conditions 1, 2 and 3 of Theorem 1. Corollary 1 now follows.  $\square$

**Corollary 2.** *If in  $H$  the number of chords  $n$  is such that  $3 \leq n \leq L$ , then  $H$  is bigeodetic.*

*Proof.* By Theorem 2, every pair of vertices belonging to  $C$  has a unique geodesic in  $H$ . Let  $u, v$  be two vertices belonging to the chord system of  $H$  such that  $u \in A_i, v \in A_j, i \neq j$ . Knowing that the pair of chords  $A_i$  and  $A_j$  (including chords  $A_i$  and  $A_j$  that are adjacent) lie on two cycles  $C'$  and  $C''$  formed by these two chords and their two corresponding inner and outer arcs subtended by them, it can be verified that if  $u$  and  $v$  are not  $C'$ -opposite, then the pair of vertices  $u$  and  $v$  are joined, either in  $C'$  by a unique geodesic  $\Gamma(u, v)$  or in  $C''$  by a unique geodesic  $\Gamma(u, v)$  (if that geodesic lies on  $C''$ ). If vertices  $u$  and  $v$  are  $C'$ -opposite, then  $u, v$  are joined, either in  $C'$  by two geodesics  $\Gamma(u, v)$  or in  $C''$  by one or two geodesics  $\Gamma(u, v)$  (if that geodesic lies on  $C''$ ). Therefore,  $H$  containing  $n$  chords,  $3 \leq n \leq L$ , is bigeodetic.

**Corollary 3.** *The embedded even cycle  $H$  of Theorem 2 is either geodetic if  $n = 2$  or bigeodetic if  $3 \leq n \leq L$ .*

**Theorem 3.** *Any minimal even cycle  $C$  (an even cycle  $C$  of minimal length) contained in a geodetic graph  $G$  generates an embedded even graph  $H$  (in the sense of Theorem 2) that is a subgraph of  $G$ .*

*Proof.* Since  $C$  is a minimal even cycle, there are no even cycles of length less than  $|C|$  in  $G$ . Now, since  $G$  is geodetic, by Lemma 1, it must happen that  $d_G(x, y) < d(C)$  for any pair of  $C$ -opposite vertices  $x, y$  in  $G$ . Therefore, the vertices of  $C$  must be joined in  $G$  with a set of paths that eliminates the nongeodeticity of all pairs of  $C$ -opposite vertices. According to Theorem 2, in  $G$ , a system of chords among those paths must be found for  $C$  satisfying conditions 1 and 2. Therefore, for  $C$  as a minimal even cycle contained in  $G$ , graph  $G$  must generate an embedded even graph  $H$  as its subgraph.

**Corollary 4.** *Let  $G$  be a connected graph. If in  $G$  there exists at least one minimal even cycle  $C$  that does not generate the embedded even graph  $H$  of Theorem 2 as a subgraph of  $G$ , then  $G$  is not geodetic.*

### Concluding Remarks

So far, a classification of geodetic graphs includes families of the following type: odd cycle graphs, cacti lacking even cycles, complete graphs  $K_n$  and the homeomorphic to them  $K_n^i$ , geodetic graphs involving sec-

tion subgraphs of complete graphs (among them, barbell graphs, lollipop graphs, windmill graphs, triangular snake graphs), both the Petersen graph and Hoffman-Singleton graph together with some special families homeomorphic to them, trees, clique trees, some special types of graphs with cliques of diameter two constructed from a generalization of affine planes, some graphs of diameter three having a similar structural description to that of a Moore graph, graphs of diameter four and five constructed using triple systems and symmetric block designs and, probably, other families that are out there, but we do not know of. Generally speaking, the classification not only of geodetic graphs, but also of bigeodetic and trigeodetic graphs are unsolved problems in graph theory [1]. Every geodetic graph is also bigeodetic. With regard to the less known bigeodetic graphs, specifically the ones that are not geodetic, only few families are known: the ones described in this article named embedded even graphs, separable bigeodetic graphs, perfect bigeodetic graphs, bigeodetic graphs contractible to a geodetic one, the ladder-like structures, and bigeodetic graphs constructed using triple systems and symmetric block designs. Regarding trigeodetic graphs, they have been much less studied, but two of their constructions are described in [1]. Finally,  $K$ -geodetic graphs have several important applications. In network topology design when controlled path redundancy make them suitable if path diversity is taking into account, in routing algorithms when the property of geodecity makes easier to take routing decisions by controlling the number of shortest paths to be considered, in fault-tolerant systems if the  $K$ -geodetic network possesses a higher index of connectivity to ensure network resilience, while the controlled number of shortest paths makes easier rerouting after network failures, and in distributed computing systems for an easy design of network communication that require predictable patterns [3].

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# PEDAGOGICAL SCIENCES

## THE NEGATIVE IMPACT OF A FAILED FAMILY ON A TEENAGER AS A CAUSE OF DEVIANT BEHAVIOR

**Azadaliyeva Shiruya Muhammadali**

*Doctor of Pedagogical Sciences, Associate Professor  
Azerbaijan State Pedagogical University, Azerbaijan*

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### Abstract

In our country, modern youth is proud of their intellectual and cultural level, worldview, skills and abilities, talents, behavior and manners. However, it must be admitted that along with all the positive aspects, there are teenagers and young people who do not follow the rules of coexistence and violate the requirements of the law. Some teenagers are registered with law enforcement agencies, and some minors are distinguished by their deviant behavior. They cause concern in society with their cruelty, tendency to drug addiction, alcohol, theft, other criminal acts, and preference for slander. In this area, the school, society, and the family have certain sins. No child is born a lawbreaker. They are born as innocent, innocent babies. They need breast milk, maternal care, paternal care, and parental love, and grow up surrounded by that care and affection. However, as a result of subsequent wrong upbringing, neglectful and irresponsible approach to upbringing, and family conflicts, the child turns into a "difficult" teenager, a "difficult" young person. A "difficult" teenager does not follow the daily routine at home, does not listen to words, spoils things in the apartment, hurts children, and has problems with neighborhood children. Teenagers who need re-education also do not behave well at school and in public places, disrupt classes, and fight. As a result, parents call teachers and class teachers, and they in turn call parents for help.

**Keywords:** future, teenager, children, parents, activities

Parents are the first educators. The future fate of children depends largely on the competence of parents. Whether their children are raised as worthy citizens of the Motherland, whether they are addicted to anti-social activities, or whether they fall into the path of crime, parents are also to some extent to blame.

There is a saying: "Treat children as if you were holding a bird in your hands. Don't open your palm too wide, the bird may fly away, don't close your palm too tight, the bird may die."

This is a saying that must be concluded.

Speaking about the problems of adolescents in need of reeducation, expert and head of the Azerbaijan Children's Union K. Agazadeh notes: "We work with children aged 3 to 18. The concept of "difficult child" covers the entire age range. It cannot be limited to adolescence alone. First of all, I would like to note that a difficult teenager is not necessarily a child who is "dirty" and has a difficult fate. Recently, children and parents from fairly prosperous families have also been contacting us. Psychologists, lawyers, medical workers - a full staff that can help children and adolescents in difficult times work with children."

Work with adolescents in need of reeducation is quite difficult and multi-stage. Therefore, the upbringing of children and adolescents in the family requires a special approach.

Speaking about the causes of the appearance of a "difficult" child, adolescents in need of re-education, K. Agazadeh writes: "Violence at home (unfortunately, it is extremely widespread), upbringing problems and a failed family. "We were approached by the mother of a 12-year-old girl who was absolutely impossible to control. The child was born with a heart defect, and of course, this could not but affect the situation in the family, the mutual relations between the

girl and her parents; they protected her at every opportunity, turned a blind eye to her every action. As a result, the child began to think that she could do whatever she wanted. The situation has reached the point that the girl's mother was forced to turn to a specialist: "I'm even ready to leave home. If only it were better for her. ... It is difficult to determine exactly what motives have an impact on the personality. It is necessary to take into account social and psychological factors together. During work with a psychologist, a number of hidden reasons come to light. "In addition, working with the family is of great importance. After all, children are really very flexible and are always ready for dialogue. Unfortunately, parents may not be "communicative" enough and do not understand the depth of the problem as much as they should; mom and dad also need to change their behavior. It is also difficult to say in what conditions "difficult children" "grow up" more: "Previously, representatives of prosperous families avoided disclosing their problems with children. Now the situation is different: about half of the children who turn to us are from such families. If you try to cover up the problem for a long time, eliminate it with financial gifts or other means, the problem will not be solved, it will simply take a hidden form". According to K. Agazade, "it is impossible to re-educate or change a child who has reached the age of 16-17. We can only support him, make some corrections in his behavior, and give him advice on how to get out of the situation". According to the expert, the main problem of homeless children is their distance from their family. But they It is somewhat easier to work with. The main problems of such children are social: "We are approached by children of single mothers, drug addicts, homeless people, and representatives of the sex industry. Their main problem

is that they do not want to come to terms with the situation they are facing. "How long will I watch my father beat my mother; my parents take drugs; men come to my mother?" Their main complaints are of this nature. Another big problem is the difficulties in accessing professional help: "There are many psychological assistance centers in the country. But since they are all private, the service is paid. The amount that must be paid for assistance to such centers is between 30-100 manats. Obviously, this is not affordable for all teenagers." Therefore, it can be assumed that disadvantaged children are unable to disclose most of their problems."

The opinion of educators, psychologists, and law enforcement officials is that the difficult emergence of children in need of re-education, especially adolescents, is often due to improper family upbringing and shortcomings in upbringing. The pedagogical incompetence of parents, their lack of pedagogical education, disagreements between parents, the lack of uniform requirements among family members regarding the upbringing of children, the failure to create the necessary conditions for upbringing and the development of the adolescent's personality, the parents' failure to observe ethical rules, and unpleasant situations in their own behavior, attitudes, and communication have a negative impact on the child and hinder his or her proper upbringing. In addition, the formation of a system of values and norms in the family that does not correspond to the norms of morality and social relations, etc. complicate the upbringing of children and adolescents. A.S. Makarenko has the following opinion: "You are ashamed to give a bad product instead of a good one at your factory, at your

enterprise. It should be a greater shame for you to give bad or harmful people to society", "A child's sense of pride for his own parent can be a healthy sense of pride only when he understands the social essence of this feeling. Your own behavior is the most decisive issue. Do not think that you educate a child only when you talk to him or teach him or give him orders. You educate him at every moment of your life, even when you are not at home".

There is deep truth in these words. Parents in the family should never stop their educational influence. One cannot be indifferent to the work of education.

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**IMPROVEMENT OF THE EDUCATIONAL AND TRAINING PROCESS FOR  
TRAINING ATHLETES WITH VISUAL IMPAIRMENTS IN PARA-ARM WRESTLING****Petrenko Volodymyr**

*Honored Trainer of Ukraine,  
Associate Professor of the Department of Physical Education,  
National Technical University  
"Kharkiv Polytechnic Institute",  
Kyrpytchova str., no. 2,  
61002 Kharkiv, Ukraine*

**Petrenko Oleksandr**

*Honored Trainer of Ukraine ,  
Senior lecturer of the department of physical education  
National Technical University  
"Kharkiv Polytechnic Institute",  
Kyrpytchova str., no. 2,  
61002 Kharkiv, Ukraine*

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**УДОСКОНАЛЕННЯ НАВЧАЛЬНО-ТРЕНУВАЛЬНОГО ПРОЦЕСУ  
ПІДГОТОВКИ СПОРТСМЕНІВ З ПОРУШЕННЯМИ ЗОРУ В ПАРА-АРМРЕСТЛІНГУ****Петренко Володимир**

*Заслужений тренер України,  
доцент кафедри фізичного виховання  
Національний технічний університет  
«Харківський політехнічний інститут»,  
Кирпичова, 2, 61002 Харків, Україна*

**Петренко Олександр**

*Заслужений тренер України,  
старший викладач кафедри фізичного виховання  
Національного технічного університету  
«Харківський політехнічний інститут»,  
Кирпичова, 2, 61002 Харків, Україна*

**Abstract**

The article investigates the issue of improving the educational and training process of training athletes with visual impairments by implementing a pedagogical approach that requires the use of special equipment and simulators in para-arm wrestling. An analysis and systematization of pedagogical approaches to the development of adaptive sports and para-arm wrestling in Ukraine and the world was carried out, which made it possible to determine the main directions of improving the educational and training process of training athletes - arm wrestlers with visual impairments. The results obtained became the basis for the developed practical recommendations on the use of special equipment and simulators in the training of athletes with visual impairments in para-arm wrestling. It is shown that the use of specialized arm wrestling tables with tactile landmarks, block and traction simulators, expanders, devices for developing grip strength, as well as stabilization platforms contributes to the formation of the correct technique of performing movements, the development of special strength and the improvement of coordination abilities of athletes. The SWOT analysis of the proposed pedagogical approach to organizing the educational and training process for athletes with visual impairments in para-arm wrestling allowed us to identify its main strengths and weaknesses, as well as assess the prospects and possible risks of using specialized equipment and simulators.

**Анотація**

В статті досліджено питання удосконалення навчально-тренувального процесу підготовки спортсменів із порушеннями зору за рахунок впровадження педагогічного підходу, який потребує використання спеціального обладнання та тренажерів у пара-армрестлінгу. Виконано аналіз і систематизацію педагогічних підходів до розвитку адаптивного спорту та пара-армрестлінгу в Україні і світі, що дало змогу визначити основні напрямки удосконалення навчально-тренувального процесу підготовки спортсменів – армрестлерів з порушеннями зору. Отримані результати стали підґрунтям для розроблених практичних рекомендацій щодо використання спеціального обладнання та тренажерів у підготовці спортсменів з порушеннями зору в пара-армрестлінгу. Показано, що застосування спеціалізованих армрестлінгових столів з тактильними орієнтирами, блокових і тягових тренажерів, еспандерів, пристроїв для розвитку сили хвату, а також стабілізаційних платформ сприяє формуванню правильної техніки виконання рухів, розвитку спеціальної сили та покращенню координаційних здібностей спортсменів. Проведений SWOT-аналіз запропонованого

педагогічного підходу до організації навчально-тренувального процесу підготовки спортсменів із порушеннями зору в пара-армрестлінгу дозволив визначити його основні сильні та слабкі сторони, а також оцінити перспективи і можливі ризики використання спеціалізованого обладнання та тренажерів.

**Keywords:** adaptive sports, educational and training process, para-arm wrestling, pedagogical approach, visual impairment.

**Ключові слова:** адаптивний спорт, навчально - тренувальний процес, пара-армрестлінг, педагогічний підхід, порушення зору.

**Постановка проблеми.** Розвиток адаптивного спорту в Україні та світі зумовлює необхідність удосконалення навчально-тренувального процесу підготовки спортсменів з інвалідністю, зокрема осіб з порушеннями зору [1, 2]. Пара-армрестлінг, як силовий вид спорту вимагає високого рівня розвитку спеціальної сили, координації рухів і технічної майстерності [3, 4]. Водночас обмеження зорового аналізатора ускладнює засвоєння технічних елементів та підвищує ризик травматизму під час навчально - тренувального процесу, що потребує особливого педагогічного підходу до підготовки таких спортсменів [5, 6].

Одним із шляхів вирішення зазначеної проблеми є використання спеціального обладнання та тренажерів, адаптованих до функціональних можливостей спортсменів з порушеннями зору [7, 8, 9, 10]. Проте питання їх застосування у навчально - тренувальному процесі підготовки пара-армрестлерів залишається недостатньо висвітленим у науково-методичній літературі, що й зумовлює актуальність даного дослідження.

**Мета статті.** Дослідити шляхи удосконалення навчально - тренувального процесу підготовки спортсменів з порушеннями зору за рахунок впровадження педагогічного підходу, який потребує використання спеціального обладнання та тренажерів в пара-армрестлінгу для підвищення ефективності тренувального процесу та забезпечення безпечних умов занять.

Для досягнення мети необхідно вирішити наступні задачі:

1- проаналізувати і систематизувати педагогічні підходи до адаптивного спорту та пара-армрестлінгу в Україні і світі;

2- розробити рекомендації щодо використання спеціального обладнання та тренажерів у підготовці спортсменів з порушеннями зору в пара-армрестлінгу;

3- виконати SWOT – аналіз запропонованого педагогічного підходу до навчально - тренувального процесу підготовки спортсменів з порушеннями зору в пара-армрестлінгу.

**Основні матеріали дослідження.**

**1. Аналіз і систематизація педагогічних підходів до адаптивного спорту та пара-армрестлінгу в Україні та світі.** Спортсмени з порушеннями зору стикаються з низкою специфічних труднощів під час навчально - тренувального процесу. До основних з них належать: обмежене зорове сприйняття технічних елементів; складність орієнтації у просторі; підвищений ризик травматизму; необхідність формування точних тактильних і пропріоцептивних відчуттів [1, 5, 6; 11].

З огляду на ці фактори, навчально - тренувальний процес потребує використання спеціального

обладнання та тренажерів, які забезпечать безпечне та ефективне засвоєння техніки армрестлінгу [4; 9, 12]. Основними функціями такого обладнання є: формування правильної техніки виконання рухів; розвиток спеціальної сили верхніх кінцівок; удосконалення координації та стабілізації суглобів; зниження ризику травм; створення безпечного тренувального середовища, що дозволяє значно підвищити ефективність підготовки спортсменів з порушеннями зору [2, 12, 13].

Світова та українська практика використання спеціального обладнання та тренажерів в пара-армрестлінгу суттєво еволюціонували, перейшовши від простих механічних пристосувань до інтелектуальних систем зворотного зв'язку, що обумовлює формування сучасного педагогічного підходу до навчально – тренувального процесу спортсменів з порушеннями зору.

**Світовий досвід.** У провідних центрах підготовки спортсменів з порушеннями зору акцент зроблено на цифровізації та біомеханічному контролі. До такого контролю відносяться перелічені нижче засоби [8, 10, 14, 15].

*Електронні ручки з тензодатчиками.* Ці ручки використовуються для вимірювання сили тиску кожного пальця окремо. Дані передаються на навушники спортсмена у вигляді тональних сигналів, що дозволяє незрячому спортсмену ідеально балансувати захват.

*Вібро-тактильні системи орієнтації.* Це спеціальні манжети на передпліччі, які вібрують, якщо рука спортсмена виходить за межі безпечного кута, що мінімізує ризик переломів.

*Тренажери з магнітним опором.* В таких тренажерах замість класичних вантажів використовується електромагнітне поле, яке імітує "тремтіння" або "ривки" реальної руки суперника, що розвиває нейросенсорну реакцію кисті.

*3D-сканування та друк.* Це створення точних копій рук суперників для відпрацювання специфічного захвату «наосліп».

**Стан та досягнення в Україні.** Інтенсивний розвиток пара-армрестлінгу в Україні почався з 2015 року і вже в 2017 році спортсмени з порушеннями зору зайняли призові місця у змаганнях. На сьогодні Україна є одним зі світових лідерів у пара-армрестлінгу.

Спираючись на власний педагогічний досвід і, будучи одними з провідних тренерів у цьому виді спорту, нами сформовано в апробовано ряд власних унікальних розробок, які дозволили покращити навчально – тренувальний процес підготовки спортсменів – армрестлерів з порушеннями зору. Основні власні унікальні розробки наведено нижче.

*Авторські тактильні насадки.* Українські тренери (зокрема в регіональних центрах "Інваспорт")

використовують кастомні конусні та ексцентричні ручки з агресивною накаткою, розроблені спеціально для спортсменів – армреслерів з порушенням зору. Вони мають глибші борозни для кращого зчеплення без візуального контролю.

*Модифіковані столи із потовщеними підлокітниками.* Ці столи мають "ефект пам'яті" (Memory Foam), що дозволяє спортсмену – армреслеру з порушенням зору чітко відчувати межі фіксації ліктя через заглиблення.

*Метод "Тандемного тренування".* Використання спарених ручок, де тренер і спортсмен тримаються за один снаряд. Це дозволяє тренеру фізично передавати вектор руху безпосередньо в кисть атлета.

Представлене вище спеціальне обладнання та тренажери використовуються в технологіях для виконання ряду вправ, які направлені на забезпечення позитивного результату під час навчально – тренувального процесу. Порівняння де яких з них наведено в табл. 1.

Таблиця 1.

Використання спеціального обладнання та тренажерів в Україні та у світі

| Світова технологія                                | Українська технологія                       | Вправа           | Результат             |
|---------------------------------------------------|---------------------------------------------|------------------|-----------------------|
| Світло-звуковий стартовий блок із за-тримкою      | Аудіо-команда тренера + механічний фіксатор | Старт на реакцію | Вибухова сила кисті   |
| Ручка з електронним вимірюванням крутного моменту | Ручка з текстильною обмоткою (стропа)       | Сила пронатора   | Контроль вектора тяги |
| Роботизована рука-маніпулятор                     | Гумові петлі різного опору                  | Статичний блок   | Витривалість зв'язок  |

Як слідує з табл. 1, в Україні та світі використовується різне спеціальне обладнання та тренажери, але за допомогою них виконується ідентичні вправи, які спрямовано на досягнення однакового результату.

**2. Розроблення рекомендації щодо використання спеціального обладнання та тренажерів у підготовці спортсменів з порушеннями зору в пара-армрестлінгу.** Підготовка спортсменів – армреслерів з порушенням зору вимагає адаптації тренувального середовища шляхом використання спеціального обладнання та тренажерів, які компенсують відсутність зорового контролю за рахунок тактильних і аудіальних відчуттів [2, 11, 14].

Для спортсменів – армреслерів з порушенням зору ключовим є розвиток «пропріоцептивної пам'яті», тобто здатності відчувати положення своєї руки та руки суперника без візуального підтвердження, що обумовлює застосування спеціального обладнання та тренажерів, аналіз яких наведено нижче.

*Спеціалізовані ручки та блоки.* Використання ексцентричних конусних або циліндричних великого діаметру ручок допомагає розвивати силу хвату для утримання руки суперника «наосліп» [2, 6].

*Спеціалізовані армрестлінгові столи з тактильними орієнтирами.* Стіл для армрестлінгу обладнується контрастними за текстурою підлокітниками та подушками. Для спортсменів з повною втратою зору використовуються рельєфні мітки на ручках (штирях) та краях столу, щоб атлет міг миттєво орієнтуватися у просторі. Армрестлінгові столи з тактильними орієнтирами дозволяють спортсменам краще контролювати положення рук і корпусу. Додаткові елементи такі, як рельєфні поз-

начки, фіксатори положення ліктя, нековзкі поверхні, сприяють формуванню правильної стартової позиції [3, 9].

*Блокові та тягові тренажери.* Ці тренажери використовуються для розвитку сили м'язів плечового поясу, передпліччя та кисті. Вони дозволяють: регулювати навантаження; виконувати ізольовані вправи; контролювати амплітуду рухів; поступово збільшувати інтенсивність тренування [4, 12].

*Еспандери та гумові амортизатори.* Це еспандери, які широко застосовуються для розвитку сили хвату та витривалості м'язів кисті. Їх перевагами є доступність, мобільність та можливість індивідуального підбору навантаження [7, 13].

*Тренажери для розвитку сили хвату.* До них належать роликові тренажери, спеціальні рукоятки та пристрої для утримання ваги. Вони сприяють формуванню міцного хвату, що є ключовим елементом у пара-армрестлінгу [3, 4].

*Балансувальні та стабілізаційні платформи.* Такі пристрої використовуються для розвитку пропріоцепції, координації рухів та стабілізації суглобів. Вони допомагають спортсменам краще контролювати положення тіла під час боротьби [2, 16].

Також слід зазначити, що під час роботи зі спортсменами – армреслерами з порушенням зору важливо враховувати такі принципи, як: використання словесного та тактильного пояснення технічних елементів; поступове ускладнення вправ; постійний контроль тренера; індивідуалізація навантажень; забезпечення безпечних умов тренування. За таких умов, особлива увага приділяється правильній фіксації руки; використанню захисних покриттів; контролю техніки виконання вправ; поступовому збільшенню навантаження.

Враховуючи вищенаведене слідє, що важливим аспектом педагогічного підходу, який направлено на безпеку навчально – тренувального процесу спортсменів – армреслерів з порушенням зору є формування чітких моторних уявлень через повторення рухів і використання тактильного зворотного зв'язку.

**3. SWOT – аналіз запропонованого педагогічного підходу до навчально - тренувального процесу підготовки спортсменів з порушеннями зору в пара-армреслінгу.** Складовими SWOT-аналізу є: сильні сторони (Strengths), слабкі сторони (Weaknesses), можливості (Opportunities), загрози (Threats).

**Сильні сторони (Strengths)** – внутрішні ресурси і навички, які дозволяють спортсмену - армреслеру компенсувати порушення або відсутність зору і сформувати конкурентну перевагу за рахунок використання спеціального обладнання та тренажерів [3, 5, 6, 7, 12, 16, 17].

**Гіперсенситивність тактильного сприйняття (Пропріоцепція).** У спортсменів – армреслерів з порушенням зору наявна надзвичайна здатність «читати» намір суперника через найменші зміни напруження м'язів та положення кисті. Цьому сприяють текстуровані ручки, які посилює цей потенціал.

**Високий рівень концентрації на векторі сили.** Спеціалізовані ексцентричні тренажери дозволяють спортсмену фокусуватися виключно на відчутті опору, що веде до ідеального відпрацювання технічних елементів («гак», «верх») на рівні м'язової пам'яті.

**Адаптивна технічна база.** Наявність тактильних орієнтирів на армреслінговому столі дозволяє спортсменам – армреслерам з порушенням зору самостійно, тобто без допомоги тренера, займати стартову позицію, що розвиває автономність та впевненість у власних діях.

**Зменшення ризику травматизму.** Використання обладнання з аудіальним супроводом, наприклад - сигнали при порушенні кута, дозволяє спортсменам – армреслерам з порушенням зору контролювати безпеку руху, запобігаючи «зламу» робочого кута, що є критичним для пара-спортсменів.

**Слабкі сторони (Weaknesses)** – терміни впровадження спеціального обладнання та тренажерів, які дозволяють ідентифікувати внутрішні бар'єри, що сповільняє підготовку спортсменів - армреслерів з порушеннями зору [5, 9, 16].

**Висока вартість індивідуалізації.** Виготовлення обладнання з тактильними датчиками та специфічними текстурами такими, як аудіо-гоніометри, кастомні ручки, потребує значних фінансових витрат порівняно зі стандартним інвентарем.

**Складність самостійного налаштування.** На більшості сучасних блокових тренажерів відсутній шрифт Брайля на вагових плитах та складні карабіни, що робить спортсменів – армреслерів з порушенням зору залежним від асистента під час зміни ваги.

**Відсутність стандартизації тактильних міток.** На різних змаганнях текстура підлокітників

або форма ручок на армреслінгових столах може відрізнятися. У разі, якщо спортсмен – армреслер з порушенням зору тренується на одному типі покриття столу, то під час змагання він може втратити орієнтацію за армреслінговим столом іншого виробника.

**Обмеженість візуального аналізу помилок.** Немоżliвість спортсменам – армреслерам з порушенням зору переглядати відеоповтор своєї боротьби для аналізу помилок. Навіть із найкращим обладнанням, корекція техніки відбувається лише через пояснення тренера «на пальцях».

**Можливості (Opportunities)** – перспективи досягнення стратегічних результатів реалізації запропонованого педагогічного підходу [6, 8, 13, 14, 18].

**Впровадження AI-асистентів з аудіо-описом.** Використання камер із штучним інтелектом, які в реальному часі озвучують спортсмену – армреслеру з порушенням зору його помилки. Наприклад, «Лікоть зміщено на 2 см вправо» або «Кут розкрито до 100 градусів».

**3D-друк кастомних тактильних насадок.** Можливість створювати індивідуальні анатомічні ручки на основі сканування кистей суперника, які ідеально повторюють хват спортсмена, з яким чекає поєдинок.

**Гейміфікація тренувань (Audio-Biofeedback).** Створення тренажерів, де звук змінює тональність залежно від сили тиску. Це перетворює монотонне тренування на процес «звукової боротьби», що стимулює нервову систему.

**Інтеграція в інклюзивні цифрові платформи.** Розробка мобільних додатків, що зчитують дані з «розумних» ручок і передають їх тренеру дистанційно, що дозволяє спортсменам – армреслерам з порушенням зору тренуватися в будь-якому залі світу.

**Загрози (Threats)** – процеси або явища, що перешкоджають руху в напрямі досягнення результатів реалізації запропонованого педагогічного підходу [5, 9, 18].

**Технологічний розрив (Digital Divide).** Швидке оновлення "розумного" обладнання може призвести до того, що спортсмени – армреслери з порушенням зору з менш заможних клубів не матимуть доступу до актуальних систем тактильного фідбеку, що створить нерівні умови на змаганнях.

**Ризик травматизму через "фантомний" контроль.** Надмірне довіряння електронним датчикам таким, як звукові гоніометри, може притупити природні захисні рефлексі. У разі виходу техніки з ладу спортсмен – армреслер з порушенням зору може не вчасно відчути критичний кут, що призведе до перелому плечової кістки.

**Зміна міжнародних регламентів (WAF/IBSA).** Раптове введення заборон на використання певних тактильних накладок або електронних гаджетів на армреслінгових столах під час змагань може збити попередню підготовку спортсменів – армреслерів з порушенням зору на спеціальному обладнанні неефективною.

**Висновок по SWOT-аналізу.** За результатами виконаного аналізу слідує, що сильні сторони і можливості являються більш ефективними в порівнянні зі слабкими сторонами та загрозами за умови поєднання методів словесного та тактильного інструктування з використання спеціального обладнання та тренажерів.

#### Висновок.

Запропонований педагогічний підхід до навчально-тренувального процесу підготовки спортсменів з порушеннями зору в пара-армрестлінгу має низку специфічних особливостей, пов'язаних з обмеженням зорового контролю рухів. У зв'язку з цим провідну роль відіграють тактильні, пропріоцептивні та слухові аналізатори. Використання спеціального обладнання та тренажерів дозволяє компенсувати відсутність зорової інформації і формувати правильні рухові навички. Застосування зазначених пристроїв у поєднанні з методами словесного та тактильного інструктування дозволяє підвищити якість технічної підготовки та знизити ризик травматизму під час тренувань.

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# PHILOLOGICAL SCIENCES

## COMPLEX SENTENCES: STRUCTURE-SEMANTIC ANALYSIS AND CURRENT ISSUES

Arzu Abbasova

*PhD., Doctor of Philosophy in Philology Department of Azerbaijani Linguistics, Faculty of History and Philology, Nakhchivan State University, Nakhchivan, Azerbaijan,*

<https://orcid.org/0009-0005-3264-9538>

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### Abstract

The article examines the structure-semantic analysis of complex sentences in the context of contemporary Azerbaijani and explores the existing issues in this field. The main aim of the study is to systematically identify the characteristics of complex syntactic structures at the lexical, morphological, and semantic levels, as well as to highlight the functional and contextual distinctions of sentences.

The results indicate that the transformation of complex sentences is not limited to syntactic rules; it also involves their semantic load, pragmatic function, and contextual appropriateness. The present study demonstrates that a proper analysis of complex sentences is essential for a deep understanding of the language and for evaluating the informational structure and communicative purpose of a text.

**Keywords:** complex sentence, structure-semantic analysis, lexical level, morphological level, semantic transformation, pragmatic functions

The research employed comparative and descriptive methods, and written sources of the Azerbaijani language from different historical periods, samples of classical literature, and modern scientific-linguistic studies were systematically analyzed (Rahimli, 2005, p. 42). This approach makes it possible to investigate the structural and semantic features of complex sentences not only from a syntactic perspective but also at lexical, morphological, and pragmatic levels. The analysis demonstrates that the structure of complex sentences is not determined solely by syntactic rules; their semantic load, the subtlety of meaning relations, and their contextual use shape the functional effectiveness of the sentence.

Complex sentences are considered one of the most intricate components of the syntactic structures of a language, and their scientific investigation has both theoretical and practical significance. Although complex sentences in the Azerbaijani language were studied for a long time mainly at the syntactic level, in recent years extensive research has been conducted within the framework of the structural-semantic approach. This approach makes it possible to analyze both the structure and meaning of the sentence in an interconnected manner (Aliyev, 2012, p. 51).

The analysis of complex sentences is relevant from several perspectives:

1. Structural organization and syntactic variations – Different types of complex sentences (coordinative, subordinative, and mixed types) possess distinctive syntactic characteristics. The structure of each type, the relationship between the components of the sentence, and the use of connecting elements reveal various semantic and pragmatic functions. From this perspective, both formal and functional approaches are important in the structural analysis of sentences (Rahimli, 2005, p. 50).

2. Semantic load and the meaning relations between independent and dependent clauses – In complex sentences, subtle semantic relations exist

between the main and subordinate clauses. In subordinative sentences, the meaning of the dependent clause is connected to the context of the main clause and complements its informational content. Semantic analysis requires the precise identification of these relationships in order to preserve the semantic integrity of the sentence (Mammadov, 2010, p. 72).

3. Pragmatic and contextual functions – The use of complex sentences does not depend solely on grammatical correctness. Their communicative role in the text, as well as emphasis, rhythm, and informational effectiveness, must also be taken into account. Contextual analysis shows that the same structure may perform different functions in different types of texts. For example, in scientific texts subordinative sentences strengthen the functions of explanation and knowledge transmission, whereas in literary texts coordinative sentences enhance rhythm and emotional impact (Aliyev, 2012, pp. 54–55).

Therefore, the analysis of complex sentences should not be conducted solely at the level of syntax; their structural-semantic and pragmatic aspects are equally important. Such an approach makes it possible to gain a deeper understanding of the language, to evaluate the functional potential of sentences, and to interpret the meaning of the text more precisely.

Research in this field shows that the analysis of complex sentences is significant not only for academic linguistics but also for language teaching, translation studies, and the study of journalistic language.

Complex sentences are classified into various categories from both syntactic and semantic perspectives, and each of these categories reflects the structural and semantic complexity of the language in different ways. This typological classification plays an important role in linguistics by ensuring the systematic analysis of sentences and by helping to determine their functional characteristics.

a) Coordinative sentences – In this type of sentence, independent clauses are connected in a

parallel relationship and are joined by conjunctions such as “and,” “but,” and “however.” In coordinative sentences, each independent component retains its meaning, and the structural complexity of the sentence is mainly regulated by the function of the conjunctions. For example, in the sentence “*He went to school and successfully completed his lesson,*” both parts are independent; however, the conjunction “and” establishes the semantic relationship between them (Rahimli, 2005, p. 45).

b) Subordinative sentences – In this type, a semantic dependency exists between the main clause and the subordinate clause. The subordinate clause completes the semantic integrity of the main clause, and its absence may partially weaken the meaning of the sentence. In subordinative sentences, connective words (such as “that,” “because,” and “whether”) express the semantic relationship and support the functional purpose of the sentence. For example, in the sentence “*He read the book so that he could understand the topic better,*” the second part completes the meaning of the first part (Mammadov, 2010, p. 72).

c) Mixed-type sentences – These sentences combine both coordinative and subordinative elements within the same structure. Mixed-type sentences are semantically complex because independent and dependent clauses are connected through both parallel and subordinate relations. The analysis of such sentences is important for the precise identification of their structural and semantic characteristics. For example, in the sentence “*He went to school and studied his lesson so that he could prepare well for the exam,*” both a coordinative and a subordinative relationship are present (Aliyev, 2012, p. 55).

All these typological distinctions indicate that the correct analysis of complex sentences requires a joint consideration of their structural and semantic aspects. Analyzing each type allows for an understanding of both the syntactic complexity of the sentence and its semantic and communicative load. This approach is regarded as one of the fundamental methodological principles in contemporary linguistics (Rahimli, 2005, p. 46).

The structural-semantic approach is considered one of the main methods in the analysis of complex sentences. This approach directly links the syntactic structure of sentences with their meaning and function, allowing syntactic, semantic, and pragmatic aspects to be examined within the same analytical framework (Aliyeva, 2020, p. 58).

Structural-semantic analysis makes it possible to explore the following issues: Functional-semantic differences of various types of complex sentences – Coordinative, subordinative, and mixed-type sentences play different roles both structurally and semantically. In coordinative sentences, independent clauses are in a parallel relationship; in subordinative sentences, the dependent clause complements the meaning of the main clause; and mixed-type sentences combine both functions. These distinctions have a direct impact on sentence interpretation and the overall meaning of the text.

The impact of lexical-morphological elements on sentence meaning – In complex sentences,

conjunctions, verb tense and person forms, pronominal markers, and other morphological elements determine the meaning of the sentence and the semantic relations within it. For example, subordinative conjunctions such as “because,” “that,” and “whether” establish the semantic connection between the dependent clause and the main clause, thereby enhancing the informational load (Mammadov, 2012, p. 72).

Pragmatic load reflects the communicative purpose of the sentence within spoken and written contexts. The structural-semantic approach allows for the evaluation of a sentence’s function in the text, its emphasis, rhythm, and informational effectiveness. This feature is particularly important in the analysis of scientific, literary, and journalistic texts (Aliyeva, 2020, p. 58).

The syntactic structure of complex sentences mainly consists of three components:

1. Main clause – It is semantically independent and forms the communicative core of the sentence. The main clause carries the primary informational load within the sentence and ensures that the meanings of other components align with it.

2. Dependent clause – It complements the meaning of the main clause and establishes a semantic relationship. Such clauses are connected to the main clause through subordinative relations and contribute to the overall semantic integrity of the sentence.

3. Coordinative elements – They connect independent clauses to create semantic unity. Coordinative conjunctions (e.g., “and,” “but,” “however”) ensure a parallel semantic relationship between the clauses (Rahimli, 2005, p. 50).

The interaction between these structural components determines the phonetic and morphological complexity of a sentence. For instance, in long subordinative sentences, the use of conjunctions maintains semantic clarity, ensuring that the reader or listener does not lose the semantic connection. At the same time, coordinative elements create rhythmic and semantic balance between sentence components in extended texts.

Thus, the structural-semantic approach allows for a systematic examination of complex sentences not only in terms of their syntactic and grammatical structure but also with respect to their semantic, morphological, and pragmatic characteristics. This approach is considered one of the methodological foundations of sentence analysis in contemporary linguistics and is widely applied in both theoretical and practical research (Aliyeva, 2020, p. 60).

In modern linguistics, the analysis of complex sentences is accompanied by several current challenges, which encompass structural, semantic, and functional aspects.

1. Identification of subtle semantic relations – In complex sentences, there are delicate semantic connections between the main and dependent clauses. These connections usually support the core meaning of the sentence and shape the informational load of the text. However, in some cases, semantic relations are not explicitly expressed, making their identification an important issue in linguistics. For example, in subordinative sentences, it is essential to consider the lexical and

morphological context to correctly analyze the semantic relation between the dependent and main clauses.

2. Classification of structural variations – Complex sentences can be coordinative, subordinative, or of a mixed type. Each type has distinct structural features and functional roles. In coordinative sentences, independent clauses are in a parallel relationship; in subordinative sentences, one clause is semantically dependent on the other. Mixed-type sentences contain both coordinative and subordinative relations within the same sentence. In contemporary linguistics, the precise classification of these types remains a relevant problem, as distinguishing semantic and pragmatic differences within a sentence is not always straightforward.

3. Phonetic and morphological adaptations – Long and complex sentences undergo various adaptations in spoken and written language. In spoken language, some dependent clauses may be shortened or conjunctions may be altered, whereas in written language, the complex structure is generally maintained and morphological details are preserved. These adaptations aim to ensure semantic clarity and convey meaning without losing the semantic connection for the reader or listener.

Therefore, the analysis of complex sentences should not be conducted solely at the syntactic level; their structural-semantic and pragmatic aspects must also be carefully examined. This approach allows for a more precise understanding of language development and functional potential, as well as enhancing the informational and communicative effectiveness of the text.

4. Conceptual and pragmatic load – Complex sentences not only have a syntactic structure but also carry a conceptual and pragmatic load that determines the communicative function and informational effectiveness of the text. The conceptual load represents the meaning and central idea of the sentence, while the pragmatic load defines its functional role for the reader or listener. These two aspects are closely interconnected and shape the placement of sentences in the text, their emphasis, and the efficiency of information transmission.

The conducted analyses indicate that the structural-semantic analysis of complex sentences should not be limited to the syntactic level. Their lexical, morphological, and pragmatic aspects are equally important. This approach enables researchers to more deeply assess the developmental potential of the language, determine the functional capacities of sentences, and gain a clearer understanding of the meaning of the text.

For example, in subordinative sentences, the morphological form and lexical choice of the dependent clause, as well as its placement within the context, di-

rectly affect its informational load. Similarly, in coordinative sentences, the pragmatic use of parallel structures determines emphasis and rhythm in the text. Thus, the structural-semantic approach is essential for ensuring both the syntactic accuracy and communicative effectiveness of sentences (Mammadov, 2012, p. 77).

Research shows that the analysis of complex sentences should not be restricted solely to the syntactic level. The structural-semantic approach systematically examines the lexical, morphological, semantic, and pragmatic aspects of sentences together, thereby revealing their semantic and functional characteristics.

Complex sentences can be coordinative, subordinative, or of a mixed type in terms of both syntax and semantics. Each type differs in its semantic-functional role, the use of conjunctions, and contextual appropriateness. Structural-semantic analysis allows for the evaluation of both the semantic relationships between main and dependent clauses and the contribution of coordinative elements to the overall meaning.

The research findings indicate that:

1. The structural and semantic features of complex sentences determine their communicative purpose and informational load.

2. Lexical-morphological elements and conjunctions preserve the semantic relations and rhythm of the sentence.

3. The structural-semantic approach is one of the key methodologies in contemporary linguistics for sentence interpretation, text analysis, and practical language use.

These results demonstrate that the systematic analysis of complex sentences is important for a deeper understanding of the language, assessing the meaning and functional structure of texts, and enhancing the quality of academic, literary, and journalistic materials.

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**HARMFUL PROPERTIES OF BORROWED WORDS****Ganira Askerova***PhD in Philology, Associate Professor**Department of Azerbaijani Linguistics, Faculty of History and Philology, Nakhchivan State University, Nakhchivan, Azerbaijan*<https://orcid.org/0009-0005-7756-8029>[DOI: 10.5281/zenodo.19483298](https://doi.org/10.5281/zenodo.19483298)**Abstract**

Language is an integral part of the people's spiritual wealth, historical memory and identity. Language is the most valuable tool in understanding the world, expressing thoughts and feelings. Although the Azerbaijani language has been exposed to many foreign influences for centuries, it has preserved its rich and original structure as much as possible. The protection of the native language is the duty of every person, especially the intellectual, and the state has a legal basis in this direction. Every citizen of Azerbaijan should guard the purity of the language and give preference to using national Azerbaijani words. However, in the modern era, against the background of globalization and the development of information technologies, the increase in borrowed words from various languages, especially Russian and English, has a negative impact on the purity and development of the language. The article dedicated to this problem analyzes the impact of borrowed words on our national identity and language system on scientific grounds. Of course, it is natural that borrowed words enter our language to a certain extent, but their inappropriate use and suppression of national words damage the purity, richness and national spirit of the Azerbaijani language. In addition, borrowed words do not always correspond to the grammatical features of the Azerbaijani language. This affects the morphological and syntactic structure of the language. Language is the soul of the nation, the most important indicator of its identity and cultural heritage. During the historical development of each nation, certain words from other languages have entered its language. Although in some cases this process is perceived as a natural and necessary result, the excessive use of borrowed words can seriously harm the purity, functional capabilities and cultural uniqueness of the national language. In the historical development of the Azerbaijani language, words from Arabic, Persian, Russian and other languages have also entered our language at different times. Currently, a large number of lexical and grammatical units from English are massively entering our language. In this regard, the article examines the damage caused by borrowed words to the Azerbaijani language from a theoretical perspective, refers to existing language policy and legislative acts, the opinions of various linguists, and suggests ways to solve the problem.

**Keywords:** language, lexicon, borrowed word, language protection, law.

**INTRODUCTION**

Language plays an important role in the life of every nation. The languages of the world are in constant development and they continuously influence one another. As a result of this interaction, words pass from one language to another; that is, borrowed words gain a certain position in the lexicon of the receiving language. The influence of borrowed words primarily changes the lexical structure of a language and weakens the internal developmental potential of the native tongue. While such words, on the one hand, create conditions for the enrichment of languages, on the other hand, they also bring certain disadvantages. Especially from the standpoint of preserving the purity of our mother tongue, the excessive use of borrowed words is undesirable.

Language is not merely a means of communication; it is the most important indicator that expresses a nation's culture, history, traditions, and identity. Every language conveys the values, beliefs, knowledge, and worldview of its speakers. However, with globalization, migration, and the dominance of several major languages, many of the world's languages are facing the threat of extinction. At present, there is a need to study the importance of language preservation, the dangers faced by endangered languages, and the strategies that can be used to protect linguistic diversity. Today, the process of rapid decline in linguistic diversity is taking place worldwide.

According to UNESCO, approximately half of the more than 7,000 languages spoken in the world are under threat. Preserving languages is essential for maintaining humanity's cultural and intellectual wealth. Language preservation also supports human rights. The right to use one's language is recognized in various international declarations and conventions, including the Universal Declaration of Linguistic Rights. When people are deprived of the opportunity to use their languages in public life, education, and governance, they are deprived of their rights and agency. Currently, preserving the Azerbaijani language — whose lexical composition includes countless borrowings — in terms of its national character remains an important and pressing issue.

**MATERIAL AND METHOD**

In the study, the method of comparison and analysis of the views of various linguist scholars was employed in order to confirm the harmful characteristics of borrowed words and to present different approaches to the issue. As research material, reference was made to scientific-theoretical opinions and legal state documents.

**DISCUSSION**

The Azerbaijani language is among the languages possessing an ancient history and interesting developmental characteristics. "This language is the

second language of the Talysh, Tats, Lezgins, Ingiloy, Udis, Khinalugs and other ethnic minorities living in the Republic of Azerbaijan, and serves as a means of interethnic communication for many Georgians and Russians in our republic" (Hajiye, 2012, p. 40). Our language has always been in development from the period of its emergence up to the present day.

"When we speak of the development of a language, we mean the regular change and enrichment of the sounds, words, word combinations, affixes, grammatical relations that constitute the structure of the language, and the elements belonging to its various components" (Sultanova, 2020, p. 124).

In this process, naturally, foreign languages have had a certain degree of influence. As the prominent Russian scholar Serebrennikov stated, the development of a language has two aspects: the development of the language under the influence of the external environment and the internal development of the language. In the evolution of any language, these factors are closely interconnected (Serebrennikov, 1970, p. 198).

As languages pass through historical periods, the phenomenon of the enrichment of vocabulary occurs. At this time, the emergence of new concepts requires the formation of new lexicon. "Language is the main means of transmitting accumulated knowledge and information to the next generation. Social and socio-political changes occurring in society develop the language. New words and word combinations formed in the language emerge as expressions of newly formed concepts in society" (Nagisoylu, Sadigova, 2020, p. 10).

This process is accompanied not only by the creation of native words but also by the transfer of words and expressions from other languages into the language. A. Gurbanov, who holds a special place in Azerbaijani linguistics, notes that words pass from one language to another under various conditions and at different times, for different reasons and through a number of ways, and he identifies three such paths:

**2. Borrowings through literary and spoken language.**

**3. Mediated and direct borrowings** (Qurbanov, 2019, pp. 225–226).

A. Qurbanov attributes newly emerging concepts related to the people's development and cultural advancement to the first group. He considers words borrowed from any source language as "direct borrowings" and includes Persian and Russian words in Azerbaijani within this group.

"It is known that many foreign terms belonging to Eastern and Western languages are used in the vocabulary of the Azerbaijani language" (Cabbarova, 2020, p. 69). Eastern sources mainly include Arabic and Persian words. H. Zarinzade, in his book "*Azerbaijani Words in the Persian Language*," noted that approximately 600 words passed from Azerbaijani into Persian (Zarinzade, 1962).

Borrowed words enter a language for specific reasons and acquire an important position:

– **To express newly emerging concepts** related to the development of technology, science, arts, and

other fields as well as expanding relations, borrowed words enter our language: *syllabus, market, drone, computer terms, e-textbook*, etc.

– **They contribute to the enrichment of the language** and expand vocabulary: expressions such as *to send a message*, the use of *thought* instead of *idea*, *region*, *innovation*, etc.

– **The development and expansion of international relations** have strengthened the entry of necessary words — especially political terms — into our language: *reintegration, escalation, disinformation, delimitation*. The use of such adopted words reinforces mutual relations.

– **Borrowed words reflect the historical stages and cultural connections** experienced by a language. Words borrowed from Arabic, Persian, Russian, and English are the result of cultural, trade, and literary relations.

Borrowed words can be encountered in all the languages of the world. Indeed, "it is impossible to imagine a language that has not been influenced by other languages or that has no interaction with them" (Hummetova, 2020, p. 17). Linguists from various nations also confirm this idea. "The need for communication leads speakers of any language to come into direct or indirect contact with neighboring or culturally dominant languages... It would be difficult to find any isolated language or dialect" (Sapir, 2005, p. 268).

However, the excessive use of borrowed words harms the lexical and grammatical structure of a language. Currently, the Azerbaijani language has been subjected to unnecessary borrowings. Moreover, "those who sound the alarm about our mother tongue are right. Today, the Azerbaijani state, people, and intellectuals have a language, but they do not have the language of philosophers, that is, the language of thought. Nations that can transform their mother tongue into a language of thought are able to make distinctions. The enrichment of a language depends on written texts. The Azerbaijani language faces the problem of closure. There is a need to expand its boundaries and to transform it into a language of thought" (1). However, achieving this is difficult during periods of rapid growth in borrowed words. The excessive incorporation of borrowed vocabulary into a language hinders the natural development and purity of the mother tongue and, in some cases, violates the norms of the literary language. Especially in the contemporary period, globalization, the influence of mass media, and technological advancement have contributed to the increase of new borrowed words.

Article 5 of the *Law on the State Language* emphasizes: "In the official correspondence, documents, and statements of state bodies, organizations, and institutions, the norms of the Azerbaijani literary language must be observed" (2). The excessive use of borrowed words contradicts this standard.

In Azerbaijan, state documents adopted on language matters also prioritize the national language. The *Law on the State Language of the Republic of Azerbaijan* states: "The Republic of Azerbaijan

considers the use of the Azerbaijani language as the state language to be one of the principal characteristics of its independent statehood; it ensures its application, protection, and development, and provides a foundation for the national-cultural expression needs of Azerbaijanis worldwide in relation to the Azerbaijani language" (2).

Furthermore, Article 21 of the Constitution of the Republic of Azerbaijan, entitled "*State Language*," states: "The state language of the Republic of Azerbaijan is the Azerbaijani language. The Republic of Azerbaijan ensures the development of the Azerbaijani language. II. The Republic of Azerbaijan guarantees the free use and development of other languages spoken by the population" (3). These official documents demonstrate that the national language in Azerbaijan has a strong legal foundation. The decree entitled "*On the Protection of the Purity of the Azerbaijani Language and Measures to Further Improve the Use of the State Language*," signed on November 1, 2018, is aimed at preventing "the blatant violation of the norms of the literary language in television and radio channels, internet resources, print publications, and advertising media, as well as the noncompliance with phonetic, lexical, and grammatical rules" (5).

All of these measures justify the need to remain vigilant regarding our language. "This requires linguists to be active in both academic and public awareness efforts to protect our language" (Hasanova, 2025, p. 30).

Language data indicate that the active incorporation of borrowed words into the vocabulary leads to the following negative consequences:

1. **The purity of the mother tongue is compromised.** The use of borrowed words instead of their native equivalents creates confusion in the language. For example, in our contemporary literary language as well as in everyday speech and writing, we encounter synonyms such as *problem*, *obstacle*, and *difficulty*. In South Azerbaijan, the word *məsələ* is used for this purpose. It is a reality that, while it is possible to use the word *çətinlik* (*difficulty*), we tend to prefer the borrowed word, often without realizing that we are undermining the purity of our language. Similarly, instead of the word *proses* (*process*), the native equivalent *gədişat* can be used. As borrowed words replace native terms, the potential of the mother tongue is pushed into the background and gradually begins to be forgotten.

2. **National identity weakens.** Language is one of the primary means through which a nation expresses its national identity and culture. The excessive use of borrowed words contributes to the weakening of our national identity. When the mother tongue is not used to its full potential, attachment to national values and traditions diminishes. The influx of foreign words into the mother tongue leads a people away from their roots. The inappropriate and excessive use of borrowed words also undermines the original spirit of national literature, folklore, and traditional poetry. Consequently, the cultural values expressed through language decline. As the number of borrowed words increases, the ability to think and express oneself in the mother tongue

diminishes, and national-cultural values are relegated to the background.

3. **The simplification of the language is harmed.** Historical evidence shows that as borrowed words increase, the internal regularities of the language are disrupted, creating confusion in the lexical-grammatical system and word formation rules. This leads to a reduction in the richness of the language and limits the possibilities for expressing thoughts. Moreover, it becomes more difficult for new generations to speak and write correctly in their mother tongue. Sometimes borrowed words are used even when they are unnecessary. Native equivalents are forgotten, replaced by borrowed words, which results in the loss of the originality of the language and its artificial exposure to foreign influences.

4. **Negative impact on the grammatical system of the language.** Borrowed words sometimes do not conform to the grammatical structure of the national language, creating inconsistencies in its structure. For example, it becomes difficult to decline or pluralize borrowed words according to Azerbaijani grammar rules, which disrupts the natural fluency of the language. Consequently, grammatical rules are violated, and correct learning of the mother tongue becomes challenging. Expressions that are difficult for the broader public to understand emerge. In particular, young people and children face difficulties in learning the pure vocabulary of their mother tongue. In general, borrowed words do not fully adapt to the phonetic and morphological rules of the language, resulting in grammatical inconsistencies.

5. **Confusion and misunderstanding in the language.** When borrowed words are used inappropriately and excessively, especially among the younger generation and students, their meanings are not fully understood. For example, words such as *monitoring*, *coordination*, *innovation*, and *implementation* can be difficult for ordinary citizens to comprehend when used unnecessarily in daily speech. In contrast, the use of native equivalents such as *yoxlama* (*checking*), *uzlaşma* (*agreement* or *reconciliation*), *yenilik* (*novelty* or *innovation*), *tətbiq* (*application*), or *yerinə yetirmək* (*to carry out*) would be more appropriate.

It is clear that borrowed words, especially those that have been in use for a long time, cannot be completely eliminated from a language. However, it is possible to mitigate their negative effects. In this regard, the following recommendations are appropriate:

1. **Pay attention to terminology creation.** For new concepts, terms should be created by utilizing the internal resources of the Azerbaijani language.

2. **Prioritize speaking and writing in the mother tongue.** In daily communication, extensive use of native words should be encouraged, and Azerbaijani language lessons should be given priority in schools that operate in other languages.

3. **Conduct awareness-raising activities in secondary and higher education institutions.** Particularly among the younger generation, the richness and potential of the mother tongue should be promoted, and efforts should be made to prevent the inappropriate use of borrowed words.

**4. Consider strong language policies at the state level in mass media.** Special attention should be paid to the purity of the language in television, radio, and print media. Additionally, relevant institutions should implement measures to protect and preserve the mother tongue.

#### Conclusion

The study has identified the following key points:

- The excessive use of unnecessary borrowed words, i.e., words that have native equivalents, undermines the purity of the language.
- It weakens national identity.
- It damages the grammatical structure of the language.
- It increases alienation and incomprehensibility in communication.

Completely banning borrowed words is neither possible nor necessary. The incorporation of borrowed words into a language in certain contexts is natural and inevitable for the development of the language. However, excessive and inappropriate use of borrowed words undermines the purity of the language, weakens national identity, and hinders the transmission of our mother tongue in its pure form to future generations.

Every Azerbaijani citizen has a responsibility to preserve the purity of the mother tongue and to approach borrowed words with sensitivity. Therefore, every individual should use Azerbaijani words instead of borrowed words whenever possible. Our mother tongue is a source of our identity and pride. Showing love and care for our language is both a national duty and obligation.

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# PHYSICAL SCIENCES

## THE ROLE AND IMPORTANCE OF SOCIOLOGY IN BOXING

**Salimzade Baba-Ali Ramazan**

*Azerbaijan Sports Academy, teacher*

ORCID: 0009-0001-7159-9167

**Israfilov Isa Gulaga**

*Azerbaijan Sports Academy, master*

ORCID: 0009-0003-3900-878X

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### Abstract

This article analyzes the role and importance of sociology in boxing from a scientific and practical perspective. It examines the impact of social relationships, group dynamics, coach–athlete interaction, and social support mechanisms on a boxer's psychological preparation and athletic performance. The study demonstrates that boxing is not merely a sport based on physical abilities, but also a complex socio-psychological phenomenon. The social environment, mentorship, public expectations, and cultural values directly influence an athlete's motivation, emotional stability, and long-term development. The findings highlight that sociology plays a significant role in boxing at both individual and societal levels.

**Keywords:** sociology, boxing, social support, motivation, psychological preparation, sport and society.

**Introduction.** Sociology is a science that studies society and human behavior in the context of social relations. Sport, as a social institution, reflects the values, norms and behavioral models of society. Boxing, especially since it is an individual and contact sport, is more sensitive to the influence of social and psychological factors. For this reason, the role of sociology in the field of boxing is particularly relevant. Sport is not only a physical activity, but also a platform for social interaction. It forms qualities such as cooperation, competition, leadership, responsibility and discipline between individuals. At the same time, sport reflects the culture, social structure and value system of society and plays a mediating role in the transmission of these values to the new generation. In this regard, sport and sociology are closely related fields.

Boxing, due to its specific characteristics, is of particular interest to the research object of sociology. In addition to being an individual and contact sport, boxing is characterized by high emotional tension, competition and physical risk factors. These characteristics highlight the social and psychological resilience of the athlete. The success of a boxer depends not only on the level of physical fitness, but also on the social support system, coach-athlete relationships, club environment and societal expectations. [5]

In addition, boxing is perceived in many societies as a symbol of strength, endurance, determination and fighting spirit. This in turn affects the social status, public image and self-identification process of the athlete. Social expectations and public opinion sometimes act as a source of motivation, and sometimes as a factor of psychological pressure. These complex interactions further actualize the role of sociology in the field of boxing. Thus, boxing is not only a demonstration of physical skills, but also a complex phenomenon formed as a result of the interaction of social relations, cultural values and psychological processes. For this reason, the role of sociology in the field of boxing is of particular

relevance and is considered an important direction in terms of scientific research. [3,4]

**1. Social support and motivation.** The success of a boxer does not depend only on physical fitness. Family, friends, coach and club environment are the main social factors that shape the athlete's motivation. Social support: increases self-confidence, reduces stress and competition tension, strengthens purposeful activity. Studies show that athletes with a strong social support mechanism recover faster from injuries and defeats.

**2. The role of the coach and social mentor.** In boxing, the coach is not only a technical guide, but also a social mentor. He: forms the athlete's behavioral model, strengthens the sense of discipline and responsibility, and helps maintain psychological stability. The coach-athlete relationship is a model of social interaction, and this model directly affects the athlete's performance.

**3. Group dynamics and social skills.** Although boxing is an individual sport, the training process takes place in a group environment. Sparring, team training and the club environment develop the athlete's: cooperation skills, principles of respect and fair play, and social adaptation. These social skills are applied both on the sports field and in everyday life.

**4. Social pressure and psychological preparation.** During the competition, the expectations of the audience, public opinion and social status can have both positive and negative effects on the athlete. Sociology allows us to understand and manage these pressure mechanisms. Psychological stability, emotional control and focus are closely related to the social environment. [1,2,7]

**5. Boxing and the formation of social values.** Boxing transmits certain social values to society: discipline, patience, fairness, responsibility, fighting spirit. These values play an important role in the social development of young people. Boxing clubs are also important in terms of social integration and promotion of a healthy lifestyle.

**6. The impact of boxing on society.** Sociology studies the social functions of boxing. Boxing: effectively organizes the leisure time of young people, can reduce the risk of criminal behavior, strengthens social integration, promotes a healthy lifestyle. Thus, boxing is not only a sports activity, but also acts as a social institution.

**Conclusion.** The analysis conducted shows that sociology plays an important role in the sport of boxing. It: explains the social and psychological behavior of the athlete, elevates the role of the coach to the level of social mentoring, shows the connection of boxing with society and culture, and contributes to the long-term development of the athlete. Thus, boxing is not just a physical fight, but a platform for social and psychological development. Sociology plays an important and multifaceted role in the sport of boxing. It not only explains the social and psychological behavior of the athlete, but also influences their formation and development. The system of social relations, group dynamics, and social support mechanisms determine the motivation of the boxer, his emotional stability directly determines the quality and competition performance. Sociology raises the role of the coach from the framework of technical management to the level of social mentoring. The coach plays an important role in the formation of the athlete's value system, the development of a sense of discipline and responsibility, as well as in social adaptation. This creates conditions for the athlete to have a successful social behavior model both in his sports career and in everyday life. At the same time, sociology clearly reveals the interaction of boxing with society and culture. Boxing strengthens the social integration of young people, promotes a healthy lifestyle and contributes to the reduction of social risk factors. The sports environment serves to form important social values such as discipline, fairness, fighting spirit and responsibility in young people. Thus, boxing is not only a field of physical struggle, but also a platform for social and psychological development. Sociology explains this process on scientific grounds and shows that behind the success of an athlete lies not only physical preparation, but also a strong social environment, proper mentoring and a healthy psychological base.

#### **Scientific innovation and applied significance.**

The topic "The role and importance of sociology in boxing" is considered one of the relevant and innovative directions from a scientific point of view. The main scientific novelty of this topic is that boxing is studied not only in terms of physical fitness and technical skills, but also in terms of social relations, social environment and the influence of society. Traditionally, boxing has been approached more from a physical and tactical perspective. However, the sociological approach allows for a deeper study of the interaction of this sport with society, the formation of athletes in the social environment and the social functions of sport.

The scientific novelty of the research conducted on this topic is related to the assessment of boxing as a social institution. That is, boxing is not only a competition and training process, but also an area that affects the formation of certain social values in society. From this point of view, boxing is studied as one of the tools that plays an important role in the socialization

process of young people. The study shows that during boxing training, athletes acquire not only physical strength, but also social values such as discipline, responsibility, teamwork and respect for the opponent. Another scientific novelty of the topic is the study of the influence of the social environment and social factors on the results of athletes in boxing. From a sociological point of view, the success of an athlete is closely related not only to his individual abilities, but also to his family environment, the team he trains with, his relationship with the coach, and the attitude of society to sports. This approach more clearly shows the role of social factors in the development of boxing and creates conditions for obtaining new scientific results in this area.

**Applied significance of the study.** The applied significance of the study is also quite broad. The results obtained are of practical importance for boxing coaches, sports organizers, and specialists working in the field of sports. In addition, the results of the study can also be used in the field of attracting young people to sports. Promoting boxing, especially among teenagers and young people, helps them to adopt a healthy lifestyle, get rid of bad habits, and increase their social activity. In this regard, boxing is not only a means of competition and achieving results, but also a factor that plays an important role in the social education of young people. The applied significance of the study is also evident in the sports education system. Studying this topic in higher and secondary specialized sports educational institutions helps future coaches and sports specialists to have a broader worldview. At the same time, the results of this study are also important for the formation of sports policy and the improvement of the activities of sports organizations. State and sports organizations can implement new programs and projects, taking into account the social role of boxing. This can make a significant contribution to the development of sports in society and the spread of a healthy lifestyle. As a result, it can be noted that the topic "The role and importance of sociology in boxing" is of great importance both from a scientific and practical point of view. The scientific novelty of the topic is associated with a deeper study of the social aspects of boxing. Its applied significance is expressed in the use of this knowledge in the process of sports training, in the education of young people and in the formation of sports policy. Therefore, the sociological approach plays an important role in the development of boxing and the comprehensive formation of athletes.

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# THE UNIVERSE IS NOT EXPANDING! WHAT IS THE ERRORS ON WHICH THE HYPOTHESIS OF AN EXPANDING UNIVERSE IS BASED?

**Gurevich G.**

*Doctor in Physics and Mathematics,  
Institute for Integration and Professional Adaptation,  
Israel, Netanya*

**Ilyev O.**

*Dr.-Engineer (energetic),  
Israel, Netanya Institute for Integration and Professional Adaptation,  
Russia, Moscow*

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## Abstract

The article proves that the apparent process of removing macrotels in the galaxy and the conclusion about the expanding Universe arises in the human mind as a result of studying the motion of these macrotels in moving reference frames.

**Keywords:** mathematical model; star system; center of equal pressure; force; pressure.

In order to understand the reason for the process of shifting the light spectra from stars and galaxies that are registered by detectors (spectroscopes) on Earth, we will study this process using the example of the motion of the planets Mars and Earth.

We will place a light source on Mars, and study the behavior of the spectrum of light emitted by a source, located on Mars.

We will study the spectrum in two reference systems:

- in a conventionally fixed reference system of the Sun. The distance between the planets Earth, Mars and the light source on Mars is constant
- and in a moving reference system of the Earth. The distance between the Earth, Mars and the light source located on Mars changes cyclically.

We will place the first observer in a conventionally fixed reference system, associated with the Sun, and the second observer in a moving reference system, associated with the Earth, **Fig. 1**.

## 1. STUDY OF THE MOVEMENT OF THE EARTH, MARS AND THE SPECTRUM OF

## LIGHT IN A CONDITIONALLY FIXED REFERENCE SYSTEM OF THE SUN

We study the movements of the Earth, Mars and a beam of light, emitted by a source on Mars, in a conditionally fixed reference system, associated with the Sun, **Fig. 1**.

The trajectory of the planets around the Sun is a screw. The projection of the screw onto a plane, perpendicular to the axis of movement, is a circle (Copernicus system).

The vector  $\vec{l}_{(E \rightarrow S)}$  describes the Earth's movement around the Sun in a circle  $R_E$  in a conventionally fixed frame of reference for the Sun.

The vector  $\vec{l}_{(M \rightarrow S)}$  describes the movement of Mars around the Sun in a circle  $R_M$  in a conventionally fixed frame of reference for the Sun.

The vector  $\vec{v}_{(M \rightarrow S)}$  describes the trajectory of a beam of light from Mars to the Sun.

An observer on the Sun sees independent orbital movements of the Earth and Mars and a beam of light, moving toward him from Mars, while there are no radial movements of the planets, **Fig. 1**.

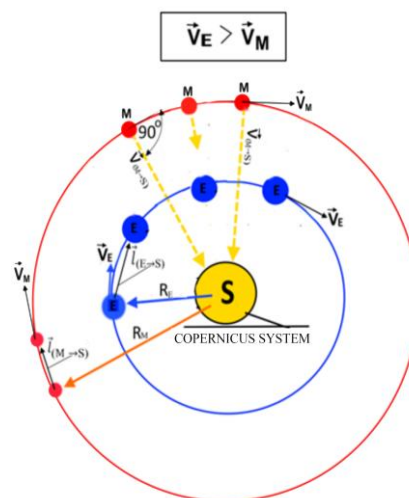


**Fig. 1.**

*The movement of the Earth, Mars, and the ray of light from Mars around the Sun*

The distance between Mars and Earth is constantly changing because both planets revolve around the Sun in their orbits. Earth makes a full revolution around the Sun in 365 Earth days, and Mars in 687 Earth days, that is, almost two Earth years.

Approximately every 780 days, the planets are closest to each other at a distance of 55-58 million kilometers. This is called opposition and corresponds to the ordinate  $7' - 8'$ , **Graph.1**.

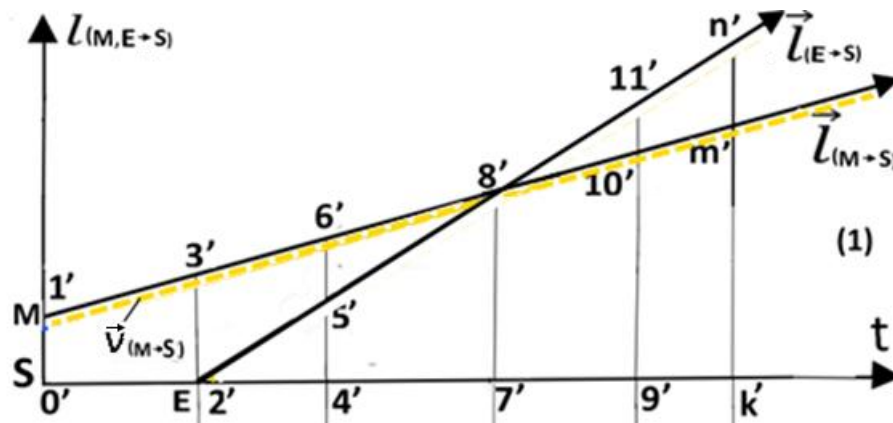
The angle of inclination between the planes of the ecliptic of Earth and Mars is  $1.85^\circ$ . An observer located on the Sun sees the movement of the planets Earth and Mars conditionally in the same plane.

**Fig. 1 and Graph. 1** show the movement of Mars  $\vec{l}_{(M \rightarrow S)}$ , Earth  $\vec{l}_{(E \rightarrow S)}$  and a beam of light  $\vec{v}_{(M \rightarrow S)}$ , in a conditionally fixed frame of reference of the Sun S.

An observer, located on the Sun in the plane of the ecliptic, sees the trajectories of the planets in the form of straight lines. The observer sees that the speed of the Earth is greater than the speed of Mars, **Fig. 1 and Graph 1**.

The spectrometer will detect a constant beam of light, carried by Mars, as it orbits the Sun.

An observer on the Sun sees Mars and the beam of light moving in the time interval  $t(O') - t(2')$ , **Graph. 1**.



**Graph.1.**

*Motion of the Earth and Mars in the reference frame of the Sun*

At  $t(2')$  the Earth appears in the observer's field of view.

At  $t(2') - t(7')$  the observer will see the Earth approaching Mars.

At  $t(7')$  the observer will see the Earth align with Mars. The Earth, Mars and the Sun are in opposition on the same straight line.

At  $t(7') - t(k')$  the Earth overtakes Mars and moves away from Mars.

#### EXPLORATION OF MARS AND LIGHT SPECTRUM MOTION IN A MOBILE EARTH REFERENCE SYSTEM

An observer on Earth is in the ecliptic plane and sees Mars approaching or moving away along a rectilinear trajectory. This rectilinear trajectory is a projection of the curvilinear orbital trajectory of Mars around the Sun.

Light beam  $\vec{v}_{(M \rightarrow S)}$  is moving in a straight line connecting Mars and Earth, at variable angles. The observer does not see the orbital motion of Mars, **Fig. 2, Graph 2**.

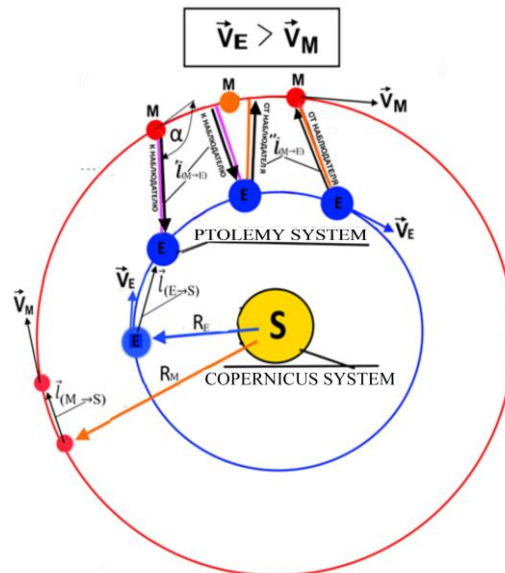


Fig.2

*The motion of Mars in a mobile reference frame associated with the Earth*

An observer located on Earth cannot determine whether he is moving or resting, and therefore cannot determine the true motion of Mars relative to Earth.

This observer sees the approach of Mars to Earth, described by the vector ' $\vec{l}_{(M \rightarrow E)}$ '. After Mars is level with the Earth, the observer will see the distance of Mars from the Earth, described by the vector ' $\vec{l}_{(M \rightarrow E)}$ ', **Fig.2**.

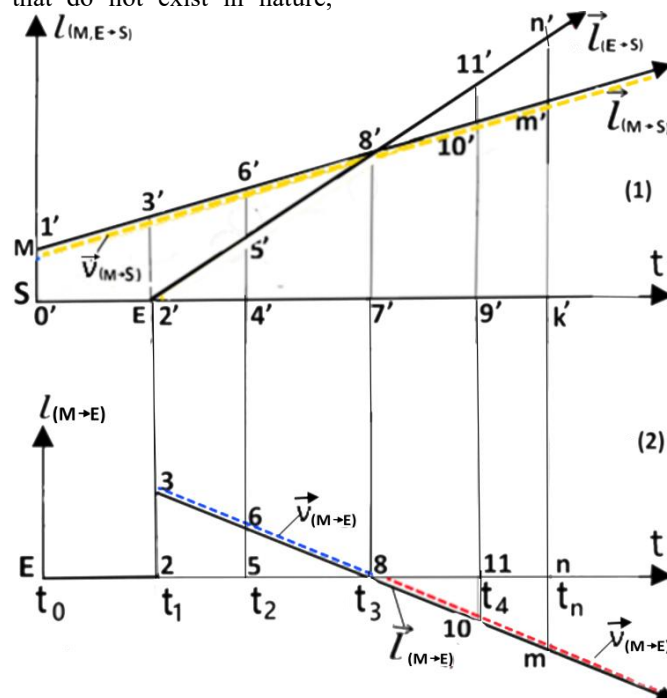
It was shown above that the Earth is moving towards Mars, so the vectors ' $\vec{l}_{(M \rightarrow E)}$ ' and ' $\vec{l}_{(M \rightarrow E)}$ ' are virtual trajectories that do not exist in nature,

formed only in the imagination of an observer located on Earth.

$\alpha$  - is the angle of incidence of a light beam from a light source on Mars, that is constantly changing due to the movement of the Earth and Mars, **Fig.2,(2)**.

A change in the angle of incidence of the light beam into the spectrometer causes the spectrum to shift to the blue or red regions.

Let us graphically depict the process of motion of Mars and the spectrum of light in the Earth system, **Graph.2, (2)**.



Graph.2

*The movement of the Earth and Mars in reference systems associated with the Sun (1).*

*The movement of Mars in the reference frame associated with the Earth (2).*

The **Graph.2(1)** shows the true movements of Mars and Earth, which are seen by an observer, located in a conventionally stationary Solar system. We examined this graph above, **Graph 1**.

**Graph 2(2)** shows the apparent movement of Mars, which is formed in the imagination of an observer, located in the Earth's frame of reference.

**Graph 2(2)** is obtained by subtracting the ordinates of the motion of Mars and Earth around the Sun. For example, from the ordinate ('4 - '6) moving Mars at time  $t_2$ , we subtract the ordinate ('4 - '5) moving the Earth in the same time  $t_2$ . We received ordinate the movement of Mars ('5 - '6) relative to the Earth, **Graph.2(1)**. Postponing ordinates (5-6)= ('5 - '6) on the **Graph.2(2)**.

By examining the movements of bodies in the moving frames of reference, it is impossible to determine the true movement of bodies among themselves. That's why it's on the **Graph.2(2)** in the Earth's frame of reference, Mars is moving towards Earth. The article above shows that in nature the Earth is moving towards Mars.

To determine the true motion of bodies, it is necessary to study the movement of bodies in a conditionally fixed frame of reference, in which all the bodies under study are simultaneously observed.

Such a frame of reference is the Sun.

There is a graph in the reference frame of the Sun, **Graph. 2(1) and Fig.1**, it can be seen that the macro-bodies Earth and Mars are moving along their independent real trajectories.

**Graph. 2(2)** shows the virtual approach of Mars to the Earth up to the moment  $t(3')$ , described by the virtual vector  $\vec{l}(M \rightarrow E)$ , and the virtual removal of Mars from the Earth after the moment  $t(3')$ , described by the virtual vector  $\vec{l}(M \rightarrow E)$ , in the moving reference frame of the Earth.

From astronomical observations it is known for sure that the Earth has a higher orbital speed than Mars.

Therefore, in reality, the Earth is approaching and moving away from Mars.

Therefore, estimating the motion of Mars in the mobile reference system of the Earth leads to erroneous results.

The study of the motion of macro-bodies among themselves must be carried out in an external, conditionally stationary frame of reference. In the conditionally stationary frame of reference of the Sun, the Earth, having a high speed, approaches Mars and overtakes it.

Einstein's theory of relativity explores the processes of motion of bodies relative to the moving frames of reference. This contradicts Galileo's principle of relativity and leads to erroneous results.

Galileo's principle of relativity states: "in the stationary reference system XYZ and in the moving reference system  $X', Y', Z'$ , the process of body movement does not change, but is transferred by the moving reference system  $O_{X', Y', Z'}$ ."

Let us turn to this postulate formulated by Einstein.

"All the laws of nature are the same in all inertial frames of reference."

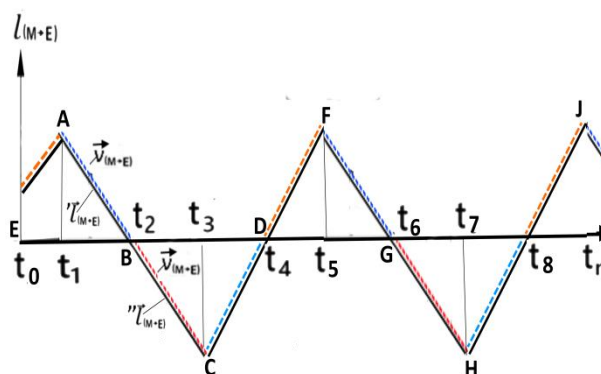
Here are the words of the physicist J. Zeldovich.

"The theory of relativity, created in 1905, concludes that when moving to a moving coordinate system, the passage of time changes, the laws change..."

The study of processes in moving frames of reference leads to erroneous results.

### THEORETICAL PROOF OF THE CAUSES OF CYCLIC SHIFT OF THE SPECTRUM

Let's move on to **Graph. 3**. This graph describes the cyclic shift of the spectrum to the violet and red regions, when the Earth moves with a greater orbital speed than the speed of Mars.



Graph. 3

The solid black line describes the virtual movement of Mars relative to Earth.

The red dotted line describes the shift of the spectrum to the red region.

The purple dotted line describes the shift of the spectrum to the violet region.

An observer located on the Earth, moving around the Sun in time  $t$ , sees a periodic virtual, apparent, imaginary approach of Mars to the Earth and the removal of Mars from the Earth, Graph 3.

Graph 3 shows the virtual cyclic approach of Mars to the Earth and the virtual removal of Mars from the Earth in the moving reference frame of the Earth.

On the graph, the black line AB describes the virtual apparent approach of Mars to the Earth  $\vec{l}(M \rightarrow E)$ , the purple dotted line describes the light spectrum

shifted to the purple region  $\nu(M \rightarrow E)$ , the line BC describes the virtual apparent distance of Mars from the Earth  $\vec{l}(M \rightarrow E)$ , the red dotted line describes the light spectrum shifted to the red region  $\nu(M \rightarrow E)$ .

The angle of incidence  $\alpha$  of the light beam constantly changes cyclically as can be seen in **Graph 3**. This occurs due to the orbital, transverse movement of the light beam from Mars to Earth. Radial movement of Mars and the light beam does not occur in nature.

In the interval  $t_1 - t_2$ , Mars approaches the Earth in the observer's imagination.

It has been proven above that in nature, the Earth moves toward Mars and transfers the spectrometer to the violet region of the spectrum, and moving away from Mars transfers the spectrometer to the red region of the spectrum.

After the Earth overtakes Mars at the moment of time  $t_2$ , Mars in the observer's imagination will move away from the Earth in the interval  $t_2 - t_3$ . In reality, the Earth moves away from Mars and transfers the spectrometer to the red region of the spectrum of the source on Mars. The light, registered by the spectrometer on the Earth, shifts to the red region.

At point "C" Mars will begin to approach the Earth. In the interval  $t_3 - t_4$  the observer sees the approach of Mars. The flow of light shifts to the violet region. And so on.

## Conclusion

The Earth, during its orbital motion around the Sun, periodically approaches Mars and moves away from Mars.

The Earth, approaching Mars, transfers the spectrometer to the blue-violet region of the spectrum, and moving away from Mars, transfers the spectrometer to the red region of the spectrum.

The shift of the light spectrum on Earth occurs due to the orbital movement of the Earth and Mars. Radial movement of Mars and the light beam relative to the Earth and the Sun does not occur in nature.

## JUSTIFICATION OF THE SHIFT SPECTRA OF THE RADIATION OF THE STARS OF VEGA, SIRIUS AND CANCER DEPENDING ON THEIR MOVEMENT IN A CONDITIONALLY FIXED REFERENCE SYSTEM OF THE CENTER OF THE GALAXY

Let us move on to the study of the motion of the stars of our galaxy and the spectra of light fluxes emitted by them, **Fig. 3**.

The figure shows the Hertzsprung-Russell diagram, demonstrating the visible parts of the radiation spectra of the stars of our galaxy closest to the Sun, obtained by telescopes on Earth.

From the diagram it follows that there is no predominant shift of the spectra of stars to the red region, on which the statement about the receding stars in the galaxy and galaxies in the Universe is based.

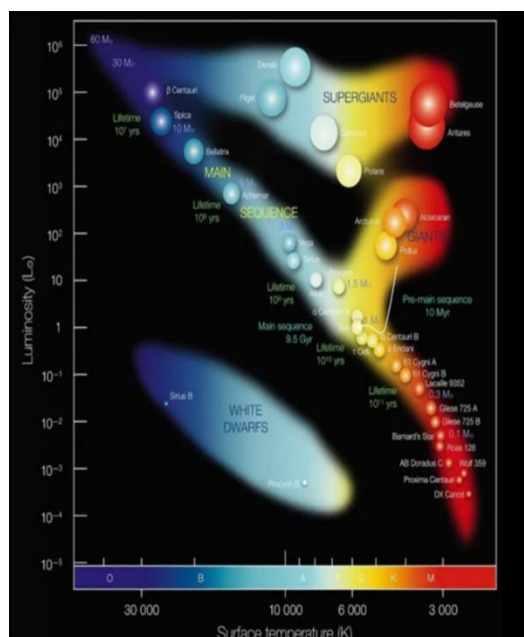


Fig.3

### Hertzsprung-Russell diagram

We will study the motion of the stars of our galaxy Vega, Sirius and DX Cancri and the behavior of the light spectra, emitted by these stars in a conditionally stationary reference frame, associated with the center

of the galaxy, **Fig. 4, (a)**, and in a moving reference frame, associated with the Earth, **Fig. 4, (b)**.

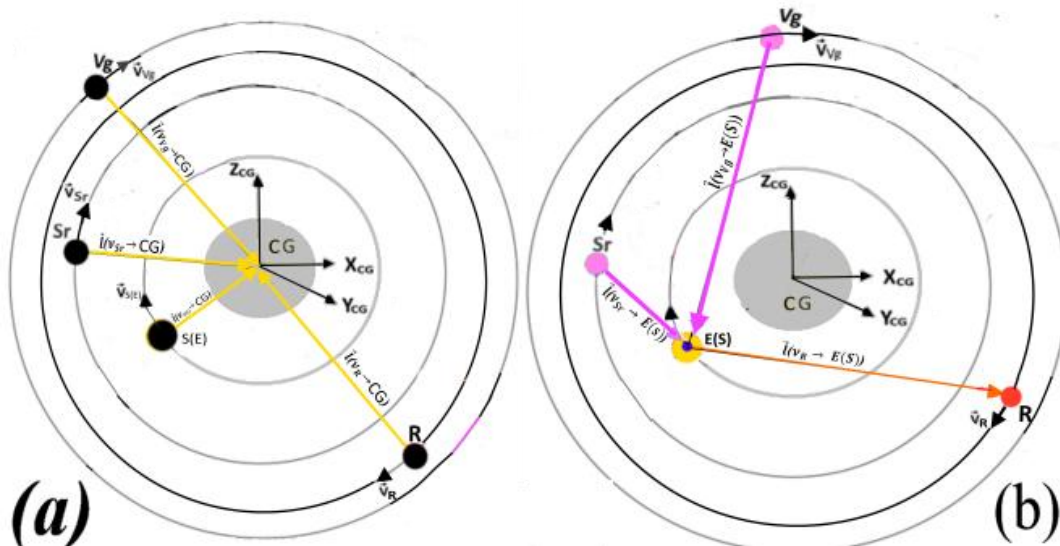


Fig.4

Diagram of the motion of the stars of the Sun, Sirius and Vega in various reference frames

The distance between the Sun and Vega is 26 light years. The distance between the Sun and Sirius is 8.6 light years. The distance between the Sun and the star DX Cancer is 11.82 light years. The distance between the Sun and the Earth is 150 million km, which is negligible compared to the distance between the stars.

For this reason, in the further study we will conditionally combine the Earth with the Sun and designate the Earth-Sun E (S), with which we will connect a mobile reference system.

**Fig. 4, (a)** shows the process of movement of Sirius, Earth-Sun, Vega and the star DX Cancer in a conditionally fixed reference frame associated with the center of the galaxy.

The vector  $\vec{l}(Sr \rightarrow C(G))$  describes the motion of Sirius in the reference frame associated with the center of the galaxy, the vector  $\vec{l}(E(S) \rightarrow C(G))$  describes the motion of the Earth-Sun in the reference frame associated with the center of the galaxy, the vector  $\vec{l}(Vg \rightarrow C(G))$  describes the motion of Vega in the reference frame associated with the center of the galaxy, the vector  $\vec{l}(R \rightarrow C(G))$  describes the movement of Cancer in the reference frame associated with the center of the galaxy, **Fig. 4, (a)**.

An observer located in the center of the galaxy will see that Sirius, the Sun, Vega and Cancer move around the center of the galaxy along the trajectories of certain radii and in the same direction. The observer sees that the stars catch up and overtake each other, not approaching the observer.

Stars emit light in the interval of  $4\pi$  steradians. The observer and spectrograph will determine that the light is directed radially to them and there will be no shift in the spectrum, **Fig. 4(a)**.

Based on the analysis of the spectrum of stars rotating relative to the center of the galaxy, it follows that the stars do not radially move away from the center of the galaxy.

### INVESTIGATION OF STAR MOVEMENT AND SPECTRUM DISPLACEMENT IN A MOVING EARTH-SUN REFERENCE SYSTEM

**Figure 4 (b)** shows the process of motion of the stars Sirius, of the Earth-Sun, Vega and DX Cancer in the mobile reference system of the Earth.

The vector  $\vec{l}(Sr \rightarrow E(C))$  describes the movement of Sirius, the vector  $\vec{l}(Vg \rightarrow E(C))$  describes the movement of Vega, the vector  $\vec{l}(R \rightarrow E(C))$  describes the movement of Cancer in the reference frame associated with the Earth-Sun, **Fig. 4(b)**.

The spectrometer on the Earth-Sun records the shift of the light spectrum from Vega and Sirius to the blue-violet region, and from Cancer to the red region due to the transfer of the spectrometer by the Earth-Sun. An observer located on Earth-Sun sees that Vega and Sirius are approaching the Sun, and DX Cancer is moving away from the Sun. In fact, all stars move in the same direction around the center of the galaxy.

Thus, both the Earth with the Sun and Vega and Sirius and Cancer and all 400 billion stars of the galaxy, emitting light, rotate around the galactic center and do not move out of the galaxy, that is, the galaxy does not expand.

Since stars do not move away from the center of the galaxy, therefore, the galaxy does not expand. Let's move on to proving that the spectrum of light emitted by the stars of the galaxy in the direction of the Earth shifts over time, **Fig.5**.

Since the Earth-Sun approaches Sirius and Vega, therefore, the Earth-Sun will eventually overtake Sirius and Vega. **Figure 5, (b)** shows the position of the Earth-Sun  $\vec{l}(E(S) \rightarrow CG)$ , Sirius  $\vec{l}(Sr \rightarrow CG)$ , Vega  $\vec{l}(Vg \rightarrow CG)$  and Cancer  $\vec{l}(R \rightarrow CG)$  after about 100 million years. This is about half the revolution of the Sun around the center of the galaxy, since the Sun makes a complete revolution around the center of the galaxy in 250 million years.

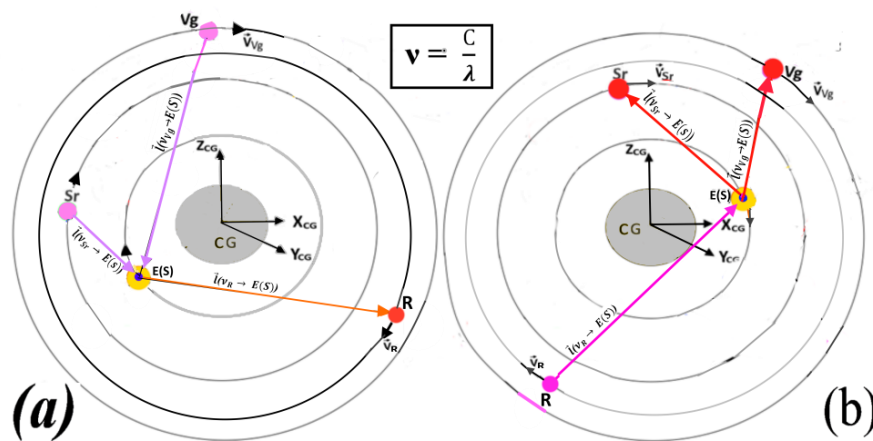


Fig.5

Diagram of the motion of the stars of the Sun, Sirius and Vega in different time periods

In this position, the Earth-Sun is already moving away from Sirius and Vega and approaching Cancer.

As you can see in the historical period shown in **Figure 5 (b)**, the shift of the spectrum of light from the stars of Sirius and Vega will be already in the red region of the spectrum, since the Earth is moving away from them, and the shift of the spectrum of light from the star of Cancer will be in the blue region of the spectrum, since the Earth is approaching the star of Cancer.

**This article proves that the displacement of the light spectra is associated not with the radial removal of stars scattering after the so-called "Big**

**Bang," but with the transfer of the spectrometer by the Earth-Sun to the stars along orbital trajectories.**

The spectrometer on the Earth-Sun determines the displacement of the spectrum of the approach of the Earth with stars or the distance of the Earth-Sun from stars. The shift in the light spectrum from stars has nothing to do with the radial distance of stars from the center of the galaxy.

**Fig. 6** simulates the process of moving the spectrometer to the violet region when the Earth approaches Sirius and moving the spectrometer to the red region of the spectrum when the Earth is away from Cancer.

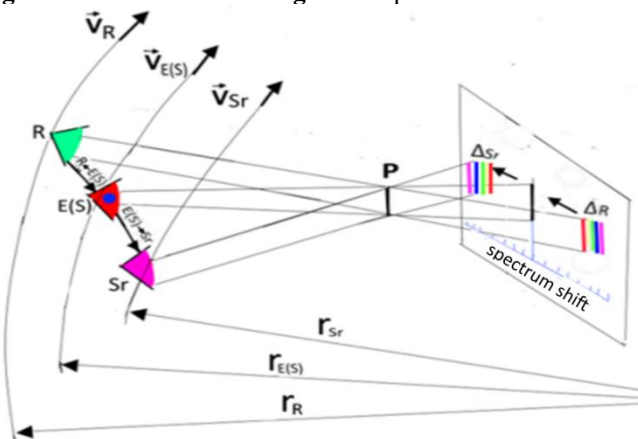


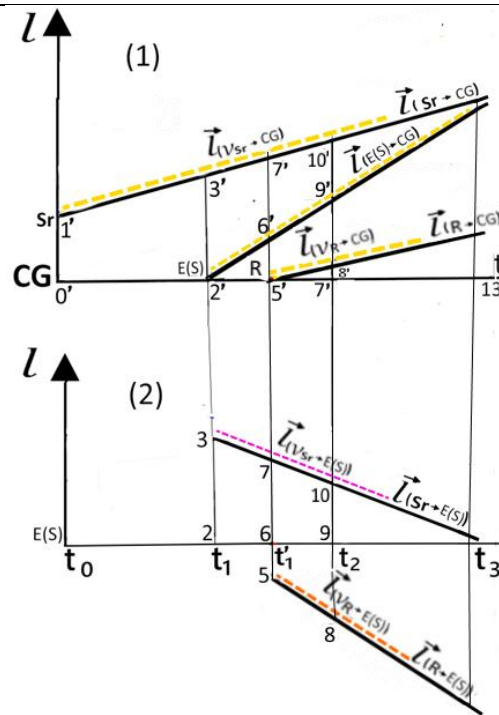
Fig. 6

Red and Purple Spectrum Shift Model

The radii of the trajectories of the Sirius and Cancer light sources are indicated by  $r_{Sr}$  and  $r_R$ .  $\Delta_{Sr}$ ,  $\Delta_R$  – are the spectra of Sirius and Cancer stars.

▪ The arrows indicate the direction of movement of the spectrometer to Sirius and from Cancer. The shadow on the conventional screen indicates the lines of the spectrum of light scattered by the prism P.

When the spectrometer moves with the Earth E (S) to Sirius, the spectrum shifts to the blue-violet region of **Fig. 6**. When the spectrometer moves with the Earth E (S) from Cancer, the spectrum shifts to the red region of **Fig. 6**.

**Graph. 4**

*Shift of the light spectrum in the mobile Earth reference system*

**Graph 4, (1)** shows the movement of the Earth-Sun  $\vec{l}(E(S) \rightarrow CG)$ , Sirius  $\vec{l}(Sr \rightarrow CG)$  and Cancer  $\vec{l}(R \rightarrow CG)$  in time  $t$  in a conditionally fixed reference frame associated with the center of our galaxy **CG**.

**Graph 4, (2)** shows the shift of the  $v$  light spectra from Sirius  $\vec{l}(v_{Sr} \rightarrow E(S))$  to the observer (purple dashed line) and Cancer  $\vec{l}(v_R \rightarrow E(S))$  from the observer (red dashed line). The observer is located in the mobile frame of reference Earth - Sun  $E(S)$ .

### Conclusions

During its orbital movement around the center of the galaxy, the Earth-Sun periodically approaches and moves away with the stars Vega, Sirius and Cancer with a period of 125 million years.

The Earth-Sun approaching the stars of the galaxy, using the example of approaching Vega and Sirius, transfers the spectrometer to the blue-violet region of the spectrum, and moving away from the stars of the galaxy using the example of moving away from Cancer, transfers the spectrometer to the red region of the spectrum.

The shift of the light spectrum to the Earth-Sun occurs due to the orbital movement of the stars of the galaxy and the Earth-Sun around the center of the galaxy.. The radial movement of the stars of the galaxy relative to the Earth - the Sun does not occur in nature.

### STUDY OF GALAXY DISPLACEMENT AND SPECTRUM DISPLACEMENT IN FIXED METAGALACTIC REFERENCE SYSTEM AND IN MOBILE EARTH-SUN REFERENCE SYSTEM OF MILKY WAY GALAXY

It can be assumed that galaxies rotate around the center of equal pressure of metagalaxy, similar to the rotation of planets around stars (centers of equal pressure), stars around the centers of equal pressure of galaxies.

The sky panorama obtained by NASA, **Fig. 7**, shows that there is no predominant redshift of the spectra, that is, there is no predominant scattering of galaxies, therefore, there is no expansion of the Universe.

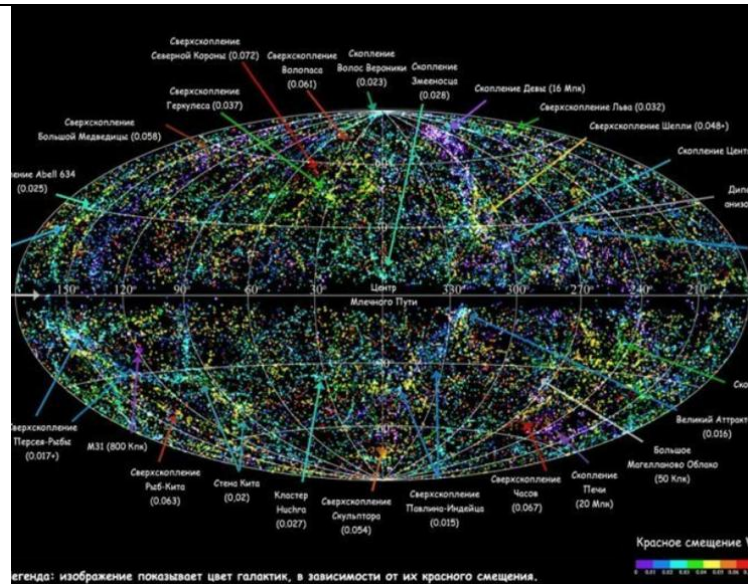


Fig.7

The sky panorama obtained by NASA

Figures 8 (a) and (b) show the movement patterns of the Milky Way and Andromeda galaxies at various historical points in time.

Figure 8 (a) shows the approach of the Earth - Sun system E (S) of the Milky Way MW galaxy with the

Andromeda galaxy as they move along orbital trajectories around the conditionally fixed center of metagalaxy (MG), and the movement of the spectrometer to the Andromeda galaxy in a mobile reference frame associated with the Earth.

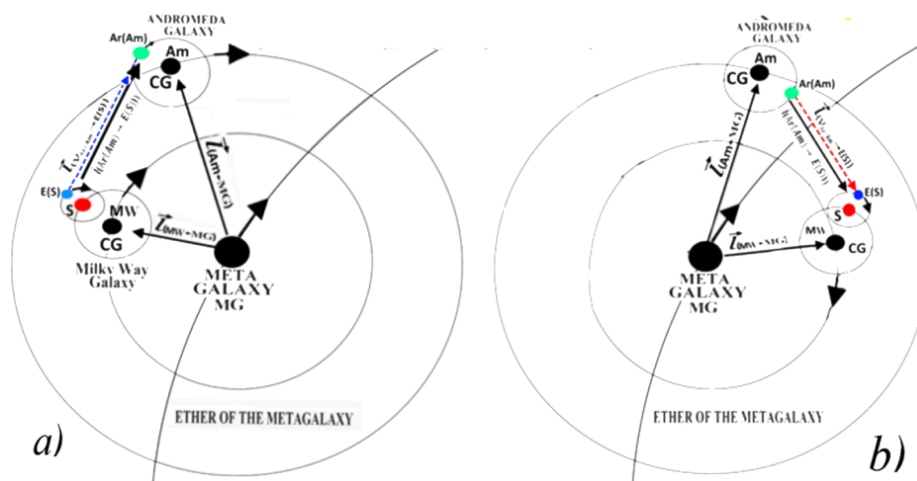


Fig.8

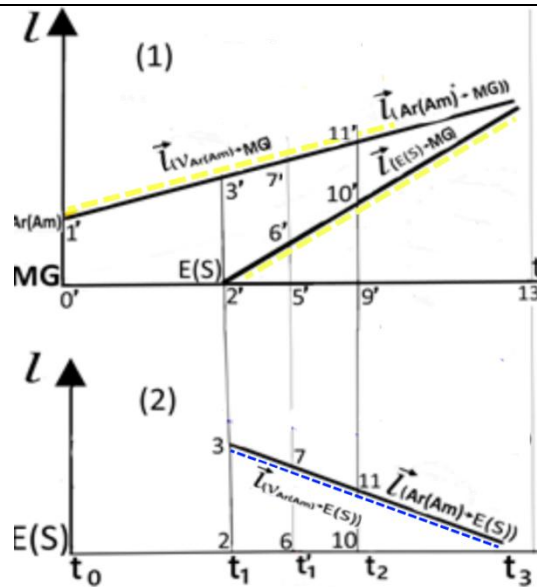
The positions of galaxies in various historical periods, separated from each other in time by billions of years

We study the movement of the galaxies Andromeda and the Milky Way and the streams of light emitted by them in a conditionally fixed reference frame, associated with the center of metagalaxy, and in a mobile reference frame, associated with the Earth.

It has been experimentally established that the spectrum of light from the Andromeda galaxy on Earth is shifted to the blue region of the spectrum.

Based on this, it was concluded that the Andromeda galaxy is approaching the Milky Way galaxy.

We study the causes of the displacement of the light spectrum of the Andromeda galaxy, recorded by spectrometers on Earth in the Milky Way galaxy, Graph 5.



Graph.5

*Andromeda Galaxy Light Spectrum Shifts Observed on Earth*

Based on the fact that the distance between the galaxies of the Milky Way and Andromeda is 2.6 million light years, and the size of the Milky Way galaxy is 100 thousand light years, in this analysis the galaxies can be considered as points.

**Graph 5, (1)** shows the process of moving the Earth-Sun and a graph of the movement of the Andromeda galaxy in a conditionally fixed MG reference frame, associated with the center of metagalaxy. The dotted line of yellow indicates the movement of light flow from the Andromeda galaxy to the center of metagalaxy.

**Graph 5, (2)** shows the process of moving the Andromeda galaxy in the time interval  $(t_1 \div t_3)$ , which is formed in the imagination of an observer, located in a mobile reference frame associated with the Earth-Sun in the Milky Way galaxy. The dotted line of blue indicates the shift of the light spectrum from the Andromeda galaxy to the Earth-Sun. The blue color of the dotted line means that the Andromeda galaxy is virtually approaching the Earth-Sun.

An observer located in a moving frame of reference, associated with the Earth-Sun, in the time interval  $(t_1 \div t_3)$  sees the movement of the Andromeda galaxy moving towards it, **Graph.5, (2)**. In addition, it records the shift of the light spectrum from the Andromeda galaxy to the blue part of the spectrum.

At the same time, the Andromeda galaxy and the Milky Way galaxy do not move away from the center of metagalaxy, but move along certain trajectories around the center of metagalaxy.

The shift of the light flux to the blue region of the spectrum, emitted by Andromeda and fixed on the Earth-Sun, is associated with the transfer of the spectrometer on Earth to the blue region of the Andromeda light spectrum.

**Figure 8, (b)** shows the position of the Andromeda galaxy  $\vec{l}(Am \rightarrow MG)$  and the Milky Way galaxy  $\vec{l}(MW \rightarrow MG)$  in a conditionally fixed reference frame associated with the center of MG metagalaxy. This will happen after the Milky Way galaxy, having an orbital speed greater than the speed of the Andromeda galaxy, overtakes the Andromeda galaxy. This process will take place in the future historical period, in billions of years. In the historical period shown in **Fig. 9, (b)** the shift of the light spectrum from the Andromeda galaxy will be in the red part of the spectrum. In this case, for an observer, located in a mobile reference frame associated with the Earth-Sun (Milky Way Galaxies), the Andromeda galaxy will **move away** from the observer. In the observer's imagination, the process will change to the opposite of what he sees in **Fig.9, (a)**.

### Conclusions

Galaxies in metagalaxy, like stars in the galaxy, like Sirius and Vega, do not move away from the center of metagalaxy, as the «Big Bang» hypothesis and Einstein's theory of expansion of the Universe claim, but move along orbital elliptical trajectories around the center of metagalaxy.

This analysis shows, that the displacement of the spectra of light, emitted by galaxies into the red region, alternates with the displacement of the spectra, emitted by galaxies into the blue region.

The results of this analysis can be extended to all stars of the Milky Way galaxy, to all galaxies in metagalaxies, and to all metagalaxies in the Universe.

# PSYCHOLOGICAL SCIENCES

## A COMPARATIVE SYNTHESIS OF COGNITIVE INFLEXIBILITY AND SELF-REGULATION IN SUBSTANCE USE DISORDERS

**Jala Mugaddas Javadova**

*Senior student of Khazar University*

*Department of Psychology*

ORCID ID: 0009-0006-2646-4585

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### Abstract

Drug addiction is a serious public health problem at the global level and is particularly prevalent among the young population. This phenomenon directly affects not only health, but also the economic and social development of the country. According to the World Health Organization (2023), diseases related to alcohol and illicit drug use account for 5.4% of the global disease burden and approximately 50 million people suffer from this problem (WHO, 2023). Executive function impairments are a central, debilitating feature of substance use disorders, with significant implications for treatment and recovery (Goldstein & Volkow, 2011). This research synthesizes evidence from neuropsychological and neuroimaging studies to examine the nature, specificity, and clinical impact of these cognitive deficits.

Findings consistently demonstrate broad and significant executive dysfunction in individuals with drug dependence, encompassing domains of inhibitory control, working memory, cognitive flexibility, and decision-making, as evidenced by poor performance on standardized assessments like the Frontal Assessment Battery and Iowa Gambling Task (Bechara et al., 2001).

Crucially, while alcohol abuse is robustly associated with deficits in verbal fluency and decision-making, illicit substances such as cocaine, cannabis, and opioids exhibit both shared and distinct patterns of impairment, moderated by the quantity and duration of use (Rogers & Robbins, 2001). Neurobiological models link these deficits to dysregulation in prefrontal and cingulate cortical networks, which are further implicated in heightened attentional bias towards drug-related cues (Volkow et al., 2012).

**Keywords:** drug addiction, executive functions, neuropsychological analyses, mental health, treatment

**Introduction** Drug addiction represents one of the most profound and complex challenges to global public health and individual well-being and is characterized not only by compulsive substance-seeking behavior but also by significant alterations in brain function and structure (Volkow et al., 2016). Modern models of addiction have evolved to move beyond purely reward-centered explanations to emphasize critical dysfunctions in higher-level cognitive processes, commonly referred to as executive functions (Hester & Yucel, 2010; Goldstein & Volkow, 2002). These functions, which include planning, decision-making, inhibitory control, working memory, and cognitive flexibility, serve as the foundation for self-regulated, goal-directed behavior and are essential for successful adaptation to the demands of life (Diamond, 2013).

A strong body of neuropsychological and neuroimaging evidence consistently identifies significant impairments in these executive domains in individuals with substance addiction (Verdejo-García et al., 2004). As Al-Hakeem and Chowdhury (2019) demonstrated, individuals with drug addiction perform significantly worse on comprehensive assessments such as the Frontal Assessment Battery (FAB) and the Rey-Osterrieth Complex Figure Test (RCFT) compared to healthy controls, revealing widespread deficits in abstract reasoning, planning, and visuospatial memory. Such impairments are not simply related to intoxication, but appear to be enduring features of the addicted brain, persisting into periods of abstinence, thereby re-

presenting addiction as a chronic cognitive control disorder (Fernandez-Serrano et al., 2010; Gould, 2010).

The relationship between substance use and executive dysfunction is bidirectional and multifaceted (Verdejo-García & Bechara, 2009). On the one hand, chronic drug exposure has neurotoxic effects, particularly on the prefrontal and cingulate cortices—brain regions that are integral to executive control (Hester & Yucel, 2010; Goldstein & Volkow, 2011). On the other hand, premorbid deficits in executive function, which are often observed in at-risk groups, such as adolescents with a family history of addiction or conduct disorder, may predispose individuals to the initiation and progression of substance use (Hester & Yucel, 2010; Tarter et al., 2003). This creates a vicious cycle in which early impairments in self-control facilitate drug use, which in turn further erode the neural substrates necessary for recovery and abstinence.

Adding to this complexity is the reality of poly-substance use. Most clinical groups do not abuse a single substance, and the confounding effects of common co-abused drugs, especially alcohol, must be disentangled to understand specific neuropsychological profiles (Fernandez-Serrano et al., 2010). Fernandez-Serrano et al.'s (2010) study highlights this complexity, showing that while alcohol abuse is strongly associated with deficits in verbal fluency and decision-making, different illicit drugs (e.g., cocaine, cannabis, heroin) exhibit both common and distinct patterns of association with impairments in components such as working memory, cognitive shift, and response inhibition. Furthermore,

parameters of use—e.g., amount and duration of use—are critical moderators of cognitive impairment, suggesting a dose-dependent relationship between drug exposure and executive dysfunction (Fernandez-Serrano et al., 2010; Bolla et al., 2004).

These executive dysfunctions have serious real-life consequences and severely impair an individual's ability to engage in and benefit from treatment (Aharonovich et al., 2006). Impairments in impulse control, foresight, and feedback adjustment directly contribute to poor treatment retention, high relapse rates, and impaired ability to cope with the challenges of ongoing recovery (Aharonovich et al., 2006; Passetti et al., 2008; Streeter et al., 2008). Therefore, a refined understanding of the specific executive function profiles associated with different patterns of substance abuse is not just an academic exercise but a clinical imperative. It is essential for the development of targeted, personalized interventions that address these cognitive deficits, thereby providing a more compassionate and effective path to rehabilitation (Hester & Yücel, 2010; Fernandez-Serrano et al., 2010).

#### **Aim of the study**

The study critically examines executive dysfunction in substance use disorders as a central mechanism underlying addiction persistence. The research aims to identify the qualitative and quantitative characteristics of executive function deficits across different substances of dependence, clarify the independent contribution of alcohol co-use in shaping executive function profiles among polysubstance users, and evaluate whether observed executive dysfunction reflects premorbid vulnerability, neurotoxic consequences of chronic substance exposure, or an interaction between both processes.

**Research question:** Do impairments in inhibitory control and decision-making significantly predict treatment retention and relapse risk in individuals with substance use disorders?

**Methods:** This research employs a structured integrative analytical design aimed at synthesizing and critically evaluating empirical evidence regarding executive function impairments in substance use disorders. Rather than collecting primary experimental data, the study adopts a comparative neuropsychological framework, drawing on previously published peer-reviewed research to examine patterns of executive dysfunction across different substances and clinical contexts.

#### **Findings of literature review**

The core empirical foundation of this analysis is based on three key studies: Al-Hakeem and Chowdhury (2019), Hester and Yücel (2010), and Fernandez-Serrano et al. (2010).

Al-Hakeem and Chowdhury (2019) employed a cross-sectional case-control design to assess executive functioning in drug-dependent individuals using standardized neuropsychological instruments, including the Frontal Assessment Battery (FAB) and the Rey-Osterrieth Complex Figure Test (RCFT). Their findings provided structured clinical evidence of global executive impairment in addicted populations (Al-Hakeem & Chowdhury, 2019). Fernandez-Serrano et al. (2010) uti-

lized a regression-based analytical approach to disentangle the independent cognitive effects of alcohol and various illicit substances, including cocaine, heroin, and cannabis. Their hierarchical regression models allowed for statistical control of alcohol use, thereby offering insight into substance-specific executive profiles and dose-dependent relationships between duration of use and cognitive impairment (Fernandez-Serrano et al., 2010; Bolla et al., 2004).

Hester and Yücel (2010) adopted a comprehensive theoretical and neurobiological review model, synthesizing findings from behavioral paradigms such as the Stroop Test, Wisconsin Card Sorting Test, Go/No-Go tasks, and the Iowa Gambling Task, alongside neuroimaging evidence from fMRI and PET studies. Their work provided a conceptual framework linking executive dysfunction to fronto-cingulate and fronto-striatal neural circuit abnormalities (Hester & Yücel, 2010; Goldstein & Volkow, 2002).

The study critically evaluates whether observed executive impairments reflect premorbid cognitive vulnerabilities, consequences of chronic neurotoxic exposure, or an interaction of both mechanisms (Verdejo-García & Bechara, 2009). This interpretation is grounded in the dual-process framework proposed by Hester and Yücel (2010) and supported by longitudinal vulnerability arguments presented in broader addiction literature (e.g., Goldstein & Volkow, 2002; Tarter et al., 2003).

Executive functions (Efs) refer to a range of higher-level cognitive processes that enable goal-directed behavior and self-regulation, including inhibitory control, working memory, cognitive flexibility, planning, and decision-making (Diamond, 2013). Dysfunction in these processes has been repeatedly identified as a core feature of substance use disorders and has been implicated in impaired judgment, compulsive drug seeking, and high rates of relapse (Verdejo-García et al., 2004; Goldstein & Volkow, 2011). The current literature demonstrates both the breadth and complexity of executive dysfunction in addiction, while also highlighting ongoing debates regarding substance-specific effects, the role of alcohol co-use, and the causal direction of these impairments (Fernandez-Serrano et al., 2010; Hester & Yücel, 2010).

A significant amount of empirical evidence supports the existence of widespread executive dysfunction among individuals with drug addiction (Verdejo-García et al., 2004). Al-Hakeem and Chowdhury (2019) provide robust clinical evidence of this phenomenon in a Bangladeshi population, demonstrating that individuals with drug addiction demonstrate significantly poorer performance in multiple executive domains compared to healthy controls. Using the Frontal Assessment Battery and the Rey-Osterrieth Complex Figure Test, their findings indicate impairments in abstract reasoning, inhibitory control, motor programming, planning, and visual working memory (Al-Hakeem & Chowdhury, 2019). Notably, these deficits were not subtle; more than two-thirds of the addicted sample scored in the clinically impaired range. Such findings reinforce the concept of addiction as a disorder involving global executive dysfunction rather than isolated cognitive impairments.

Fernandez-Serrano et al. (2010) demonstrate both common and substance-specific patterns of impairment. Cannabis and cocaine use were generally associated with deficits in working memory, reasoning, and decision-making, while long-term cocaine and heroin use predicted reduced cognitive flexibility (Fernandez-Serrano et al., 2010; Verdejo-García et al., 2005). Cocaine uniquely impaired response inhibition, while cannabis duration was associated with deficits in visual working memory (Fernandez-Serrano et al., 2010). These results contrast with the null findings reported by Al-Hakeem and Chowdhury (2019) regarding differences between drug types. Taken together, this discrepancy suggests that broad screening instruments may obscure substance-specific cognitive profiles, while multidimensional neuropsychological batteries are better suited to detect nuanced executive dysfunction (Fernandez-Serrano et al., 2010).

Hester and Yücel (2010) synthesize behavioral, neuroimaging, and longitudinal evidence to position executive control deficits as a central mechanism underlying addiction. Their review consistently links impaired inhibition, attentional control, and decision-making to dysfunction in fronto-cingulate-striatal networks, particularly in the prefrontal cortex and anterior cingulate cortex (Hester & Yücel, 2010; Bush et al., 2000).

Despite a strong consensus on the existence and clinical significance of executive dysfunction, important gaps remain (Verdejo-García et al., 2004). The direction of causality cannot be definitively established in the reviewed studies, largely due to cross-sectional designs (Al-Hakeem & Chowdhury, 2019; Fernandez-Serrano et al., 2010). Furthermore, the trajectory of cognitive recovery during sustained abstinence, particularly during early abstinence when executive control is most impaired, remains uncertain (Hester & Yücel, 2010; Schulte et al., 2014). The discrepancy between behavioral performance and neuroimaging findings suggests that traditional neuropsychological tests may underestimate underlying neural dysfunction (Hester & Yücel, 2010; Goldstein & Volkow, 2011).

**Limitations:** This study has several limitations. First, the research was limited to a comparative analysis of only three core articles, which may restrict the generalizability of findings to broader populations and clinical contexts. Second, the findings may not be representative of all substance-dependent individuals due to specific cultural and demographic characteristics of the samples examined (Bangladeshi and Spanish populations), limiting applicability to other regions, including Azerbaijan. Third, the study was conducted within a limited timeframe, preventing a more exhaustive literature review. Fourth, this research presents primarily qualitative synthesis rather than original quantitative data analysis. Fifth, the reviewed studies relied heavily on cross-sectional designs, which cannot establish causal relationships between substance use and executive dysfunction. Most included studies had predominantly male samples, limiting insights into potential gender differences.

**Future implementation:** Future research should extend beyond the three studies examined here by investigating diverse populations, particularly within

Azerbaijan rehabilitation centers, to determine whether these findings hold across different cultural contexts. Longitudinal studies are needed to clarify whether executive dysfunction precedes substance use or emerges as a consequence—a distinction with important implications for prevention and intervention. Multi-modal approaches combining neuropsychological assessment with neuroimaging would provide a more complete picture of how cognitive deficits manifest at both behavioral and neural levels. Including more female participants is essential, as current research predominantly reflects male experiences. Cross-cultural comparisons would further illuminate how social context shapes cognitive outcomes in addiction.

**Conclusion:** Evidence shows that executive dysfunction constitutes a core cognitive deficit in substance use disorders, not merely a secondary consequence of drug exposure (Al-Hakeem & Chowdhury, 2019; Verdejo-García et al., 2004). The findings demonstrate that individuals with drug dependence exhibit significant impairments across multiple executive domains, including inhibitory control, working memory, cognitive flexibility, and decision-making, with over two-thirds scoring in clinically impaired ranges on standardized assessments (Al-Hakeem & Chowdhury, 2019; Diamond, 2013).

Crucially, these deficits follow substance-specific patterns. Alcohol independently predicts verbal fluency and decision-making impairments, cannabis and cocaine share effects on working memory, cocaine uniquely impairs response inhibition, and cocaine with heroin overlap in cognitive flexibility deficits (Fernandez-Serrano et al., 2010; Verdejo-García & Rubenis, 2020). Dose-dependent relationships between duration of use and impairment severity further support neurotoxic consequences, while evidence from at-risk populations suggests premorbid vulnerability also contributes (Tarter et al., 2003; Hester & Yücel, 2010). The neural substrates underlying these deficits localize to fronto-cingulate-striatal circuits, with attentional bias to drug-related cues representing a key mechanism linking executive dysfunction to craving and relapse (Goldstein & Volkow, 2011; Hester & Yücel, 2010).

### **Recommendation**

Future research should prioritize longitudinal designs that track individuals from at-risk stages through addiction onset, chronic use, and recovery phases to clarify the temporal dynamics of executive dysfunction and definitively establish causal relationships between substance exposure and cognitive decline (Hester & Yücel, 2010; Fernandez-Serrano et al., 2010). Such studies would help disentangle the relative contributions of premorbid vulnerability factors from neurotoxic consequences of chronic drug use.

Multi-modal assessment approaches combining traditional neuropsychological tests with neuroimaging techniques (fMRI, PET) and electrophysiological measures (EEG/ERP) should be employed to capture both behavioral performance and underlying neural dysfunction, addressing the discrepancy between apparently intact performance and abnormal brain activation patterns (Hester & Yücel, 2010). Future studies should include more diverse samples with adequate

representation of female participants to investigate potential gender differences in executive dysfunction profiles and treatment outcomes, thereby enhancing the generalizability of findings (Al-Hakeem & Chowdhury, 2019; Fernandez-Serrano et al., 2010).

Research should focus on the trajectory of cognitive recovery during sustained abstinence, particularly examining the critical early withdrawal period when executive control may be most compromised, to identify optimal timing for cognitive interventions (Hester & Yucel, 2010). Cross-cultural validation studies, including research in diverse contexts such as Azerbaijan rehabilitation centers, are needed to determine whether executive dysfunction patterns observed in Western samples generalize to other cultural and clinical populations (Al-Hakeem & Chowdhury, 2019).

Clinical practice should incorporate routine comprehensive neuropsychological assessment to identify individual profiles of executive strength and weakness, enabling personalized treatment planning that addresses specific cognitive vulnerabilities (Al-Hakeem & Chowdhury, 2019; Fernandez-Serrano et al., 2010).

Rehabilitation programs should integrate cognitive remediation strategies targeting specific executive domains—such as inhibitory control training, working memory exercises, and p[decision-making skills development—alongside traditional behavioral and pharmacological interventions to strengthen the cognitive faculties necessary for sustained recovery (Hester & Yucel, 2010; Fernandez-Serrano et al., 2010).

Treatment outcome studies should examine whether cognitive enhancement interventions improve retention rates and reduce relapse risk, and whether baseline executive function profiles can predict which patients will benefit most from specific treatment approaches (Al-Hakeem & Chowdhury, 2019; Hester & Yucel, 2010).

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# SOCIAL SCIENCIES

## IDEOLOGY AND DIGITAL TRANSFORMATION IN THE MANAGEMENT OF PUBLIC OPINION: A SOCIOLOGICAL ANALYSIS

**Tazagul Mirza Gasimova**

*PhD in Philosophy, Associate Professor  
Leading Researcher Institute of Philosophy and Sociology  
Azerbaijan National Academy of Sciences  
Baku, AZ1073, H. Javid Ave. 115, , Azerbaijan  
ORCID: 0000-0002-7629-9817*

**Osman Yusif Hajiye**

*Doctor of Philosophy in Philosophy, Associate Professor  
Sumgait State University  
Sumgait city, 43rd district, Baku street 1, Azerbaijan  
ORCID: 0000-0002-5978-0676  
[DOI: 10.5281/zenodo.19483925](https://doi.org/10.5281/zenodo.19483925)*

### Abstract

This article analyzes the role of ideology in managing public opinion and the impact of digital transformation through a sociological lens. The study demonstrates that in modern society, public opinion is determined not only by social behavior and information flow but is actively shaped via ideological mechanisms and digital platforms. The article provides theoretical, conceptual, and empirical analysis within the context of Azerbaijan. The analysis reveals that public opinion management is intrinsically linked to ideology's functions of legitimacy and social control, with digital transformation significantly enhancing the efficiency of these mechanisms.

**Keywords:** Public opinion; ideology; digital transformation; social control; legitimacy; sociological analysis.

### Introduction

Public opinion plays a fundamental role in modern societies, shaping political decision-making, social stability, and the legitimacy of state authority. Since the late twentieth century, processes such as globalization, the rapid development of information and communication technologies, and the widespread diffusion of social media platforms have fundamentally transformed the mechanisms through which public opinion is managed [2].

In contemporary societies, ideology occupies a central position in the formation of public opinion. As noted by Althusser and Gramsci, ideology not only ensures the legitimacy of power structures but also facilitates the production of social consensus and the regulation of social behavior. Digital transformation further accelerates and expands these mechanisms, increasing the scope of ideological influence through social networks [1; 5].

The aim of this article is to analyze the role of ideology in the management of public opinion and to examine the mechanisms of digital transformation from a sociological perspective. In analyzing the topic, it is methodologically appropriate to follow a structured sequence.

First, it is necessary to consider the formulation of the problem. In this regard, attention should initially be given to how public opinion is interpreted within traditional sociological approaches. Traditional sociological perspectives explained the formation of public opinion primarily through social institutions and the media [3]. However, with the rise of digital transformation and social media platforms, these mechanisms have evolved, and the management of public opinion is increasingly

realized through new information flows and interactive forms of influence.

At the same time, the mechanisms of ideological influence are being reconfigured. Social media platforms strengthen the ideological influence of particular groups and are capable of shaping the direction of public opinion through both accurate and manipulative information. From a sociological perspective, this transformation necessitates a reconsideration of the concepts of legitimacy and social control [6].

The problems addressed in this article are appropriately selected for both theoretical and empirical analysis. By examining the case of Azerbaijan, the study contributes to addressing an empirical gap in this field.

Following the formulation of the problem, the analysis begins with an examination of the dialectical relationship between social control and ideology. Althusser conceptualizes ideology as a mechanism of social control, emphasizing its role in the reproduction of specific patterns of thought and behavior. Gramsci demonstrates that hegemonic ideology reinforces legitimacy through the construction of social consensus [5]. Habermas, through the concept of *legitimation crisis*, argues that deficiencies in governance and social structures may weaken legitimacy and lead to increased social unrest [6].

Within the framework of the network society theory, Castells emphasizes that information technologies play a decisive role in social, political, and economic processes [2]. Digital platforms accelerate the formation of public opinion and make its management more flexible. Similarly, Easton, within the systems approach, identifies legitimacy as a fundamental condi-

tion for the sustainability of political systems. Thus, legitimacy, social control, and ideology are interconnected in the management of public opinion, and this relationship is further strengthened by digital transformation [3].

During the analysis of the topic, it is also important to incorporate the fundamental ideas of the American journalist and public opinion theorist Walter Lippmann, whose work significantly enriches the scientific understanding of the issue. Walter Lippmann is particularly known for his work *Public Opinion*, in which he introduced new perspectives on the formation of public opinion.

His main ideas can be classified as follows:

#### 1. The Illusion of Public Opinion:

- According to Lippmann, individuals do not directly perceive events occurring in the external world; rather, they interpret them through a “pseudo-environment,” that is, a reality constructed by media and symbolic representations.

- Thus, individuals tend to rely more on images created by the media than on objective reality.

#### 2. The Concept of “Stereotypes”:

- Lippmann emphasizes the role of stereotypes in the formation of public opinion.

- Stereotypes help individuals perceive events in a simplified and easily understandable manner; however, they do not fully reflect reality.

#### 3. The Role of Experts:

- Lippmann argues that it is difficult for ordinary citizens to make informed decisions regarding complex social issues. Therefore, experts and journalists play a crucial role in ensuring that the public is accurately informed.

#### 4. Media and Democratic Governance:

- Lippmann notes that public opinion is shaped through simple, concise, and symbolic messages [7].

- For this reason, democratic decision-making often relies on information presented by the media.

From the interpretation and analysis of Lippmann's ideas, it can be concluded that public opinion may not be entirely objective, as individuals tend to perceive events through media representations and social symbols. According to Lippmann, the responsible role of educated experts and the media is essential for effective democratic participation. From a sociological perspective, public opinion is not merely a collection of individual subjective views but is also shaped by social networks, media systems, and ideological constructs [7].

- **Ideology** serves as a mechanism for structuring public opinion and framing events within specific boundaries.

- Individuals perceive complex social phenomena through simplified stereotypes, and ideology reinforces these cognitive structures [4].

From a sociological perspective, it is essential to examine the empirical indicators that play a key role in the analysis of this topic. Empirical evidence demonstrates that:

- Digital transformation facilitates the rapid formation of public opinion

- Ideology strengthens the management of public opinion through its functions of legitimacy and social control

- Interaction between the state and civil society continues to increase

The number of social media users in Azerbaijan has increased over the past decade [8]. Platforms such as Facebook, Instagram, Telegram, and TikTok play a central role in shaping public opinion. State institutions, independent media, as well as social groups disseminate ideological messages through these platforms, thereby influencing the management of public opinion.

The Azerbaijani model utilizes ideological communication tools to ensure legitimacy, including:

- Promotion of state programs and national ideology

- Presentation of historical and cultural values through social networks

- Public opinion surveys and social media monitoring

These mechanisms serve to guide public opinion and maintain social stability. The case of Azerbaijan demonstrates that the management of public opinion is achieved through the integration of ideology and digital transformation. Legitimacy ensures public consent and social stability, while digital platforms accelerate and expand the mechanisms of ideological influence. These findings confirm sociological theories and illustrate the dynamic and adaptive nature of public opinion management in the contemporary era [2; 6].

At the conclusion of the study, it can be noted that ideology and digital transformation are closely interconnected in the management of public opinion. From a sociological perspective, digital platforms intensify ideological influence and accelerate the formation of public opinion. While this creates new opportunities for democratic participation, it also increases the risks of manipulation. Future research should therefore focus on identifying ways to ensure the objectivity of public opinion within digital environments.

The results of the conducted research can be systematized as follows:

### Conclusion

The findings of the study indicate that:

- The management of public opinion is closely linked to the functions of ideology in ensuring legitimacy and social control.

- Digital transformation accelerates the formation of public opinion and enhances the flexibility of its management.

- The Azerbaijani model serves as an empirical confirmation of contemporary sociological theories and strengthens the strategic governance capacity of the state.

- This approach also provides conceptual and methodological experience for other countries in the region.

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# TECHNICAL SCIENCES

## REAL-TIME RISK ASSESSMENT IN FOREX TRADING

<sup>1</sup>Mammadova K.A.

<sup>2</sup>Sharifov P.R.

<sup>1,2</sup>Azerbaijan State Oil and Industry University.

Department of Computer Engineering. 20 Azadlig ave., Baku, Azerbaijan, AZ1010

<https://orcid.org/0000-0002-6530-2021>

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### Abstract

This article is devoted to the issue of real-time risk assessment, which is one of the biggest problems in the financial sector. In particular, it covers risk models implemented within the framework of infinite technology capabilities (INFINITECH) and their integration with relevant technological tools to ensure the processing of large volumes of input data. The presented Infinittech application, in addition to using a number of well-known risk models, also introduces a new model based on deep learning techniques. These assessments can be updated in almost real-time using streaming financial data and can be used to conduct "what if" analysis for portfolio changes.

The Infinittech solution can become a valuable tool for professionals involved in high-frequency trading - an area where consistent risk assessment in real time is required. It should be noted that the existing architecture can also be used with different risk models optimized for different financial portfolios. In addition, additional functions can be integrated into the system in the form of microservices, in accordance with the Infinittech reference architecture.

**Keywords:** portfolio risk, risk assessments, risk models, Value at Risk, Variance-Covariance approach.

### 1. Introduction

Risk assessment is required to determine the probability and magnitude of a loss on a loan or investment. Sometimes, incorrect models or incorrect assumptions can lead to large capital losses. Therefore, risk assessment and continuous monitoring are of great importance in investment banking. This was also observed in a number of financial institutions during the 2008 financial crisis and the COVID-19 pandemic. Despite the digitalization of the financial sector, many companies are far from accurate, real-time risk assessment capabilities. This is due to the fact that portfolio risk assessments are currently updated only once a day, usually in batches at night. This is not sufficient for trading in higher frequency markets such as Forex [1,2]. Surprisingly, this issue still remains an open problem for many banks and asset management companies. In these organizations, risk assessment is often outsourced to third-party consulting companies responsible for risk monitoring and regulatory compliance, and this process is carried out in accordance with a pre-agreed investment strategy. In addition, even in some cases, even if a real-time overview of trading positions is provided, the data necessary to calculate risk measures and other important indicators is updated only once a day. As a result, the level of risk arising from price changes occurring throughout the day is not properly monitored, which can lead to inefficiency in both trading and investment.

The main obstacle to real-time risk monitoring in high-frequency trading, depending on the complexity of the algorithms, is the speed of calculating financial risks. Usually, there is a certain balance between speed and accuracy in calculating financial risks. Although risk models that require fewer computational resources can provide immediate results, they are not considered

sufficiently reliable in the financial sector. In addition, real-time risk monitoring is a requirement of administrative bodies. This requirement can only be met if risk information is updated in a timely manner.

[2,3], the need for risk assessment in trading, investment and other financial processes is highlighted. This is because poor risk monitoring can lead to ineffective investments, capital losses and fines from regulatory authorities. Robust risk models that can provide real-time results are valuable assets for investment banking. This paper presents a financial tool that can provide real-time and pre-trade risk assessment of FX portfolios. Financial risk is measured in terms of both value at risk and expected shortfall. The proposed application, based on state-of-the-art data management technologies, provides real-time risk assessments using the latest market data [4]. These features, together with the pre-trade analysis provided, make this solution a valuable tool for professionals in high-frequency trading and investment banking in general.

This paper presents a new tool called Artificial Intelligence-Risk-Assessment. This tool is presented as one of the potentially important solutions in the FX market. More precisely, this tool is aimed at solving the problem of real-time risk assessment in the Forex market. The main advantages offered by this tool are divided into three main areas: risk models real-time management; pre-trade analysis. The basic architecture of the system is presented, which ensures the smooth operation of these components with each other. The proposed tool is based on a containerized microservice architecture. The system consists of various components, and these components communicate with each other asynchronously. As a result, a real-time data processing pipeline (container) is formed. This model is depicted in Figure 1 [6].

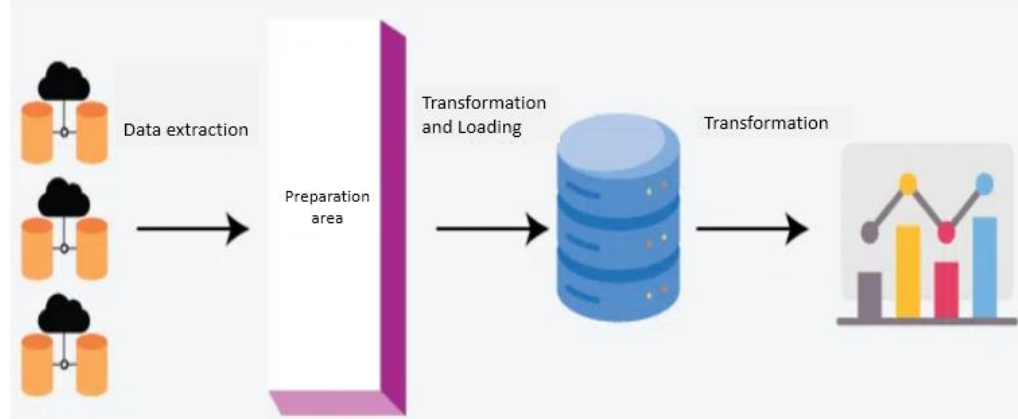


Figure 1. Data processing line [7]

## 2. Portfolio Risk

Portfolio risk is the probability that the set of assets that make up the portfolio will not achieve its financial goals. A portfolio is an investor's "basket" of financial instruments, and Portfolio risk is the risk arising from the price volatility and probability of loss of the assets in that "basket". Each capital in the portfolio carries its own risk. Thus, the higher the potential return, the greater the risk. In order to measure this risk quantitatively, the future indicators of each asset, i.e. its returns, must be predicted. For this purpose, various models and theories have been put forward regarding the nature of financial time series. Most of these models assume that the returns of the underlying assets follow a certain distribution, for example, a Gaussian distribution. They attempt to determine its parameters, the average price and variance of the asset's returns, based on past indicators. In addition, portfolio risk also depends on the weighted combination of component assets and their mutual correlation. Thus, according to Modern Portfolio Theory, which is based on the Normal distribution for financial returns, the risk indicator of a portfolio under a known probability distribution can be determined through the distribution parameters (1) [2,3]:

$$\mu_p = E(R_p) = \sum_i w_i E(R_i), i = \overline{1, n} \quad (1)$$

where  $R_p$  is the portfolio return,  $R_i$  is the return of the  $i$ th asset, and  $w_i$  is the weight of that asset in the portfolio,

$$\sigma_p^2 = \sum_i w_i^2 \sigma_i^2 + \sum_i \sum_{i \neq j} w_i w_j \sigma_i \sigma_j \rho_{ij}, i, j = \overline{1, n} \quad (2)$$

where,  $\sigma$  is the sample standard deviation of the periodic returns of the asset, and  $\rho_{ij}$  is the correlation coefficient between the returns of assets  $i, j$ .

Furthermore, the Efficient Market Hypothesis suggests that in highly efficient markets, such as the foreign exchange market, the value of a financial instrument reflects all available information about that instrument. Therefore, the risk models used must be constantly updated with the latest market data to provide reliable portfolio risk assessments. There is a particular need for continuous updating of risk assessments in high-frequency market transactions. In this area, traders mainly manage multiple portfolios based on algorithmic trading, combining different strategies — in terms of holding period, composition, risk profile and volume — [1-5,7]. Therefore, a special tool is needed that can process large volumes of market and trade data and pro-

vide risk assessments. These assessments must be updated in near real-time to reflect intraday volatility, which can lead to liquidity and capital losses.

## 3. Risk Models

The proposed application uses two main risk measurement methods that are widely used not only in risk management, but also in financial management, financial reporting and capital calculation by financial management institutions: value at risk and expected loss.

The first risk measurement method, Value at Risk (VOR), measures the maximum amount of loss that an investment can suffer over a certain period of time (usually one day) and within a certain probability of reliability. There are three main approaches to calculating VOR: parametric, non-parametric and semi-parametric [5,6,8]. The "Artificial Intelligence – Risk – Assessment" tool presents four VOR models based on these approaches in order to improve the risk monitoring process [9].

Parametric. The most widely used parametric VOR method is based on the Variance-Covariance (VC) approach. According to the main assumption of this method, portfolio returns are normally distributed and the dispersion of market data is assumed to be known [10]. In addition, a suitable "history" window should be defined and the variance-covariance matrix of returns should be calculated [11,12,13]. The VOR is calculated by formula (3):

$$V_a R^\alpha = Z_{1-\alpha} \sqrt{w^T \Sigma w}, \quad (3)$$

where,  $z$ ,  $\alpha$ ,  $w$  and  $\Sigma$  are the standard price, the probability of the VOR forecast, the weights of the portfolio assets and the covariance matrix of the portfolio assets, respectively.

Non-parametric. Among the non-parametric approaches, the well-known Historical Simulation (HS) method was chosen [14,15]. In this method, the past returns of the portfolio over a certain time window and the chosen confidence level are taken into account when calculating the VOR. As a first step, the historical portfolio returns are sorted from small to large, then the worst  $n$ -day indicator corresponding to the required confidence probability is taken as the VOR. For example, when calculating the daily 95% VOR based on 100 days of data, the best result among the returns falling in the worst 5% corresponds to the 95% VOR. Thus, TS

is a computationally efficient model that gives satisfactory results when using large historical windows. However, in this case, the VOR values are taken high, which limits the acceptable investment strategies.

**Semi-parametric.** Within the framework of the semi-parametric approach, a Monte Carlo (MC) model has been developed [10-14]. In this method, the mean and standard deviation of returns are calculated based on available historical data, and then random MC samples from a Gaussian distribution are generated using these values. To calculate RD, the distribution of portfolio returns over the future period is modeled (4):

$$V_\alpha R^\alpha = q_{1-\alpha}, \quad (4)$$

where  $q_\alpha$  is the  $\alpha^{\text{th}}$  percentile of the continuous compound return (e.g.  $\alpha = 0.05$  for a 5% risk).

**Semi-parametric with RNNs.** In addition, the tool introduces a novel semi-parametric VOR model that combines deep neural networks with ML simulations [11,13,15]. In this approach, the parameters of the return distribution are first estimated using a Recurrent Neural Network (RNN)-based model, and the network output is used to predict all possible future returns using the ML method. The VOR is then calculated using formula (4) above. This RNN model, called DeepAR, is provided by the GluonTS Python library for deep learning-based time series modeling. The model is able to capture nonlinear dependencies of the input time series, including features such as seasonality, which allows for more accurate quantile estimates. Moreover, DeepAR can accept multiple time series at the same time, which enables joint cross-learning from their historical behavior [16]. As a result, dynamic changes in one time series can affect the forecast distributions of other time series.

Risk assessment can alternatively be performed using the Expected Shortfall (ES) method, also known as Conditional Value at Risk (CVR). This is a conservative risk measure and calculates the loss on the assumption that the portfolio loss is higher than the calculated VOR. ES was initially proposed as a practical and reliable alternative to RD; one of its main advantages is the sub-additivity feature that VOR does not have. For this reason, many financial institutions have adopted it as an internal risk measure. ES can be calculated using the parametric equation (5) [10,15,16]:

$$ES_p^\alpha = -\mu_p + \mu_\sigma \frac{\phi(\Phi^{-1}(\alpha))}{\alpha}, \quad (5)$$

where,  $\phi(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}}$  is the density function,  $\Phi(x)$  is the standard normal cumulative distribution function, and  $\Phi^{-1}(\alpha)$  is the standard normal quantile;  $\mu_p$  and  $\sigma_p$  denote the mean and standard deviation of the portfolio returns, respectively.

The application's user interface offers a separate page for analyzing and back-testing the risk assessments submitted. This feature allows the user to comparatively evaluate the actual performance of different VOR/ES models at both the 95% and 99% confidence levels.

#### 4. Real-time management

Providing the above-mentioned risk assessments using the latest available data is a very difficult task. The main reason for this is that currency market prices are updated at an unevenly high frequency (e.g., 1-8

seconds). In addition, even small price changes can have a significant impact on the value of portfolios, especially in cases where a high risk/return strategy is applied. Therefore, additional technologies are needed that can combine continuous data management with online analytical processing capabilities.

Within the framework of the Infinittech project, this issue is addressed through a new data management platform called InfiniSTORE. InfiniSTORE extends the existing advanced database platform and introduces two important innovations that enable real-time analytical processing of transactional data.

1. The platform's hybrid transaction and analytical processing engine allows for very high data ingest speed and simultaneous analytical operations on that data. This eliminates the need to transfer historical data to a temporary storage that is slow and inherently batch-oriented.

2. The online aggregation function ensures efficient execution of aggregate operations, which significantly reduces the response time to queries by several times.

The implementation of the AI-Risk-Assessment model requires the data warehouse to perform two main functions: first, to store raw input ticker data and risk assessments, and second, to provide online data aggregation and integrated query processing on both the data being processed and the stored data. These requirements are met by InfiniSTORE and the underlying LeanXcale database through a dual interface. This interface allows for the reception of operational data at any speed and at the same time parallel processing of analytical queries on live data.

To achieve the main goal of the application, which is to measure risk in a timely manner throughout the day — for example, to update the RD/GC approximately every 15 minutes — the ticker data that enters must be resampled 1-8 times per second at the required frequency. LeanXcale provides an online aggregation capability that enables declarative real-time data analysis with standard SQL statements. This mechanism allows you to specify only the required aggregate operations—for example, the average price per quarter hour for each currency pair—and the result is automatically calculated in advance. This turns what would normally take a long time to perform into lightweight operations that require only a single value, eliminating the need to scan the entire data set.

#### 5. CONCLUSION

The portfolio risk assessment in the paper has a two-stage procedure.

In the first stage, both VOR and ES are calculated as separate univariate time series for each portfolio instrument based on the latest market prices obtained from the real-time management tools described in Section 4. It should be noted that these calculations are performed in the background and are automatically updated as new data becomes available.

The second stage is related to user input. For example, when the user experiments with new trading positions, the weight of each asset is determined and the VOR/ES indicators of the portfolio are calculated based on the univariate risk assessments. This procedure is

completed in a very short time, as it only requires simple matrix algebra.

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